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CONTENTS

Some ostracods from the Middle Devonian Ledyard and Wanakah members of the Ludlowville formation in western New York ..... *Marvin L. Smith* 1
Pseudoarctolepis sharpi, n. gen., n. sp. (Phyllocarida), from the Wheeler shale (Middle Cambrian) of Utah ..... *H. K. Brooks* and *Kenneth E. Caster* 9
Upper Silurian Brachiopoda from the Great Basin ..... *R. H. Waite* 15
Some notes on the genus *Dolichopterus* Hall ..... *Kenneth E. Caster* and *Erik N. Kjellesvig-Waering* 19
A new upper Canadian fauna from a deep well in Tennessee ..... *G. Arthur Cooper* 29
New cordaitean cones from the Pennsylvanian of Iowa ..... *Wayne L. Fry* 35
Acrocephalites? glomeratus Walcott, 1916 ..... *Alan B. Shaw* 46
A Cambrian *Aphelaspis* fauna from Steele Butte, near Boulder, Wyoming ..... *Alan B. Shaw* 48
Archaeolithophyllum, a new genus of Paleozoic coralline algae ..... *J. Harlan Johnson* 53
Olenellidae with advanced cephalic spines ..... *Horacio J. Harrington* 56
Anceney local mammal fauna, latest Miocene, Madison Valley formation, Montana ..... *John A. Dorr, Jr.* 62
Cephalopods from the Canadian of Maryland ..... *Rousseau H. Flower* 75
Some endoceroids from the El Paso limestone ..... *Rousseau H. Flower* 97
An *Endolobus* from the Beaver Bend limestone (Chester) of Indiana ..... *Walter C. Sweet* and *Arthur C. Brookley, Jr.* 101
Beecher's supposed odontopleurid protaspis is a phacopid ..... *Harry B. Whittington* 104
A new Mississippian tetracoral from Death Valley, California ..... *Herbert Tischler* 110
The transformation of opaque calcium carbonate to translucent calcium fluoride in fossil Ostracoda ..... *I. G. Sohn* 113
A new pinniped from the Miocene of southern California; with remarks on the Otariidae ..... *Theodore Downs* 115
A Chadron mammalian fauna from Nebraska ..... *Jean Hough* and *Raymond Alf* 132
Notes on *Modocia* and Middle Cambrian trilobites from Wyoming ..... *Alan B. Shaw* 141
The lower Pliocene Ogallala-Wolf Creek vertebrate fauna, South Dakota ..... *Morton Green* 146
A bibliography of the order Stromatoporoidea ..... *J. J. Galloway* and *J. St. Jean, Jr.* 170
A new Clarendonian mammalian fauna from the Truckee formation of western Nevada ..... *J. R. Macdonald* 186
Notes on halysitid corals ..... *G. Winston Sinclair* and *Thomas E. Bolton* 203
PALEONTOLOGICAL NOTES 207
NOMENCLATURAL NOTES 219, 221
NOTICES 220
SOCIETY RECORDS AND ACTIVITIES 222

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SOME OSTRACODS FROM THE MIDDLE DEVONIAN LEDYARD AND WANAKAH MEMBERS OF THE LUDLOWVILLE FORMATION IN WESTERN NEW YORK

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ABSTRACT.—A new genus, *Parabufina*, is described to include two new species, *Parabufina convexa* and *Parabufina postruncata*. Other new species described are *Phlyctiscapha subovata*, *Aechmina magnaspina*, *Amphizona pseudocarinata*, *Welleria bisulcata*, and *Quasillites angulatus*. A distribution study revealed but one distinct ostracod zone characterized by *Welleria bisulcata*, n. sp.

INTRODUCTION

IN MOST previous paleontologic studies of the Ledyard and Wanakah shales, writers have been concerned primarily with megafossils and have merely indicated the presence of ostracods. So far as can be determined the only detailed ostracod study encompassing the Ludlowville section of western New York published to date is the work of Coley (1954).

Ulrich (1890) and Grabau (1898) described and identified a few species of ostracods from the Ledyard and Wanakah shales exposed on Lake Erie. More recently several new genera have been described by Kesling (1953, 1954) and Kesling & Copeland (1954) from exposures of the Wanakah member in Erie and Genesee Counties, New York.

Of the 51 species of ostracods listed in this paper, only one, *Paraparchites* sp., is not identified specifically, because its poor preservation and rarity will not permit a clear understanding as to whether it is a new species or merely a moult stage of some previously described form. Seven species are new and the holotypes are in the New York State Museum, Albany, New York.

Stratigraphy.—The lower part of the Ludlowville formation (Hamilton group) in the western part of the state is represented by relatively dark shales containing a Marcellus fauna, but the upper beds are calcareous gray shales and thin limestones containing a typical Hamilton fauna. As the Ludlowville is traced east of the type section (near Ludlowville, Tompkins County, New York), the beds become thicker and more arenaceous, and the Marcellus fauna of the lower beds disappears.

In the western part of New York state the members of the Ludlowville formation are easily identified by the faunal and usually distinct lithologic differences; however, in the easternmost outcrops uniform faunas and lithologies prevent any such differentiation. The Ledyard and Wanakah shales become more nearly alike eastward from Lake Erie and cannot be differentiated east of Cayuga Lake.

Methods of investigation.—Samples of weathered rock were collected from 5-foot intervals. In many instances it was possible to wash the partly disintegrated shales in hot water with continuous decanting until a residue of ostracod valves, conodonts, megafossils, and the more resistant bits of shale and limestone remained. However, when it was necessary to use freshly exposed material, it was possible to free most of the ostracods from the matrix by pressure-cooking the shales for an hour.

The majority of the ostracods collected for this study are so well preserved that even the finer details of ornamentation are distinguishable. Most of the specimens are so substantial that, with the exception of breaking the very fragile hollow spine of *Aechmina magnaspina*, n. sp., and the female valves of *Phlyctiscapha subovata*, n. sp., a thorough washing did no appreciable damage to the valves. The method of selecting sample sizes has been previously described (Smith, 1954).

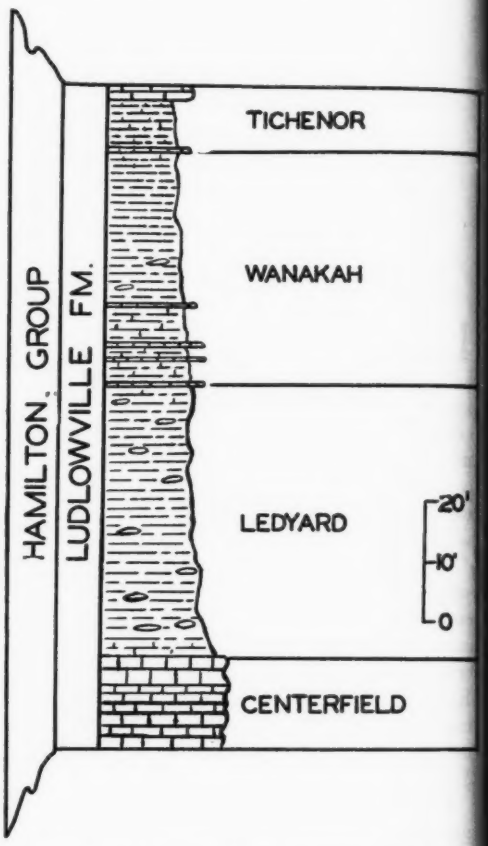
Due to a marked decrease in the number of ostracods in these shales in the central part of the state, the writer limited his investigations to outcrops occurring between Seneca Lake and Lake Erie, a distance of approximately 100 miles.

Distribution.—An increase in the lime content of the shales is frequently accompanied by a marked increase in species and numbers of shell-bearing organisms. In view of this it is not at all surprising that there should be more ostracods in the Wanakah shale than in the Ledyard member. As the Wanakah member is traced east of Genesee Valley, the lime content decreases, and this unit becomes more similar faunally to the underlying Ledyard shale. The megafossil zones which define these members also disappear eastward in the relatively limeless shales.

An examination of the tabulated distribution data (Table 1) reveals but one distinct ostracod zone. This zone, characterized by *Welleria bisulcata* n. sp., is coincident with the *Pleurodictyum* and trilobite beds of the lower Wanakah shale from Lake Erie eastward to Genesee Valley.

In sections where there is a repetition of similar lithologies, it is not unusual for the faunas to be repeated provided that the life span of each species was long enough. This was evidently the case in the Ledyard and Wanakah members. The rarity of distinct zones may, at first consideration, appear to reduce the value of ostracods as horizon markers; however, a closer examination of the distribution of these ostracod species indicates a definite distinction. A preliminary examination of the samples from the other Ludlowville members reveals a more obvious difference in ostracod faunas.

Orientation of the carapace.—The orientation of living ostracods is relatively simple because the soft parts are present. Tertiary and Mesozoic forms do not often



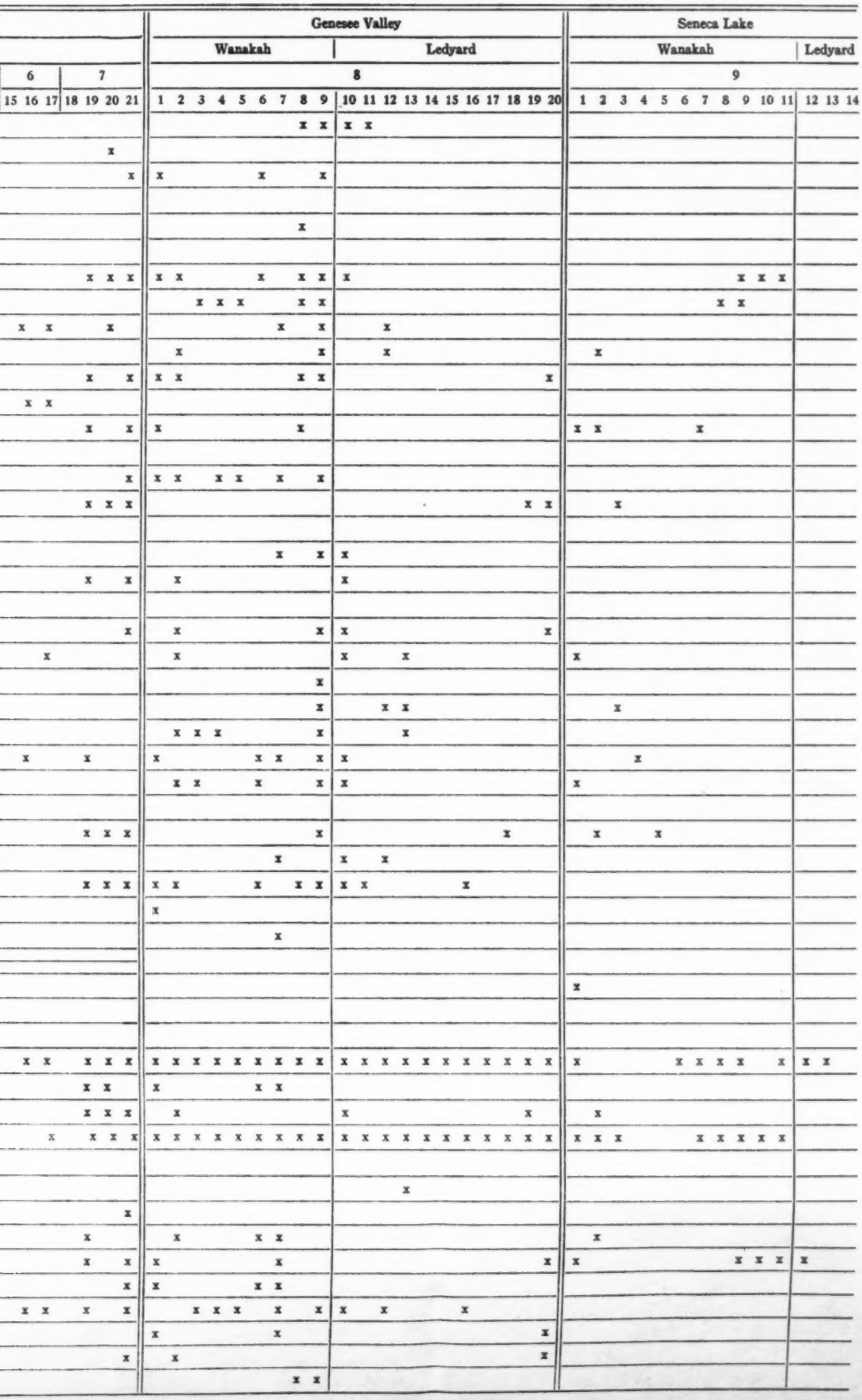
TEXT-FIG. 1.—Generalized columnar section of the Ludlowville formation (Hamilton group) exposed in Jaycox Run near Geneseo, N. Y.

20'
10'
0

Section	Lake Erie																				
Member	Wanakah													Ledyard							
Locality number	1										2			3							
Sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2
1. *Aechima* cf. *A. cuspidata* Jones & Holl, 1869																					
2. *Aechmina magnaspina* n.sp.																					
3. *Amphisona asceta* Kesling & Copeland, 1954			x																		
4. *Amphisona pseudocarinata*, n.sp.																					
5. *Arcyzona conata* (Coryell & Malkin, 1936)																					
6. *Bairdia summacuminata* Coryell & Malkin, 1936		x																			
7. *Birdsallella devonica* Coryell & Malkin, 1936	x		x						x	x	x	x								x	x
8. *Bollia hindei* Jones, 1890				x				x			x	x									
9. *Boursella trilobata* Turner, 1939						x															
10. *Bufina bicornuta* (Ulrich, 1891)			x	x						x											x
11. *Bufina elongata* Coryell & Malkin, 1936	x		x																	x	
12. *Bythocypris devonica* Ulrich, 1890																					
13. *Bythocypris* cf. *B. lucasensis* Stewart, 1936	x										x									x	
14. *Bythocypris subquadrata* var. Stewart, 1936														x	x						
15. *Coelonella plana* Stewart, 1936	x	x		x																x	
16. *Ctenobolbina papillosa* Ulrich, 1891																					
17. *Ctenobolbina windomensis* Swartz & Oriel, 1948			x																		
18. *Ctenoloculina acanthophora* Swartz & Oriel, 1948	x	x																			
19. *Euglyphella* cf. *E. compressa* Coryell & Malkin, 1936				x			x			x											
20. *Euglyphella primitiva* Warthin, 1934	x	x																			
21. *Euglyphella projecta* Coryell & Malkin, 1936	x			x	x	x		x			x										x
22. *Euglyphella sigmoidalis* (Jones, 1890)	x	x	x	x	x	x		x		x											
23. *Healdia arkonensis* Coryell & Malkin, 1936		x																			
24. *Hibbardia lacrimosa* (Swartz & Oriel, 1948)	x	x	x	x	x		x	x		x	x	x								x	x
25. *Hollina hamiltonensis* (Jones, 1890)		x	x	x		x	x			x										x	x
26. *Jenningsina divaricata* Swartz & Oriel, 1948	x	x	x	x	x	x															
27. *Kirkbyella bellipuncta transversa* Stewart & Hendrix, 1945	x		x	x	x		x	x													
28. *Kirkbyella verticalis* Coryell & Cuskley, 1934			x																		
29. *Macrocypris acutula* Stewart, 1936																					
30. *Menoeidina arcuata* Turner, 1939					x			x		x				x	x			x	x		
31. *Menoeidina scopeli* Coley, 1954	x							x		x	x								x		
32. *Monoceratina casei* Warthin, 1934																					
33. *Parabufina convexa*, n.sp.	x	x	x	x				x			x										
34. *Parabufina postruncata*, n.sp.			x			x															
35. *Parabufina subovalis* (Swartz & Oriel, 1948)																					
36. *Paraparchites* sp.																					
37. *Phlyctiscapsa subovata*, n.sp.																					
38. *Ponderodictya bispinulata* (Stewart, 1927)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
39. *Punctoprimitia subaequalis* Swartz & Oriel, 1948	x	x	x	x	x	x	x	x	x	x										x	x
40. *Quasillites angulatus*, n.sp.	x					x			x		x										x
41. *Quasillites lobatus* Swartz & Oriel, 1948	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
42. *Richina truncata* Coryell & Malkin, 1936	x		x							x											x
43. *Roundyella tenua* (Warthin, 1934)			x																		
44. *Strepulites tischleri* Coley, 1954																					
45. *Tetrasacculus minimus* (Ulrich, 1891)									x												
46. *Thrallella cristata* Swartz & Oriel, 1948	x			x																	
47. *Tubulibairdia windomensis* Swartz & Oriel, 1948	x			x	x															x	
48. *Ulrichia conradi* Jones, 1890	x					x	x	x			x										
49. *Ulrichia fragilis* Warthin, 1934	x				x																
50. *Ulrichia fragilis subnodata* Turner, 1939																					
51. *Welleria bisulcata*, n.sp.										x	x	x									

TABLE 1.—DISTRIBUTION OF OSTRACODES COLLECTED FROM LEDYARD AND WANAKAH SHALES

| | Cazenovia Creek | | | | | | | | | | | | | | | | | | | | | | | | | East Bethany | | | | | | | | | | | | | | | | | | |


Genesee Valley
Seneca Lake
Wanakah
Ledyard
Wanakah
Ledyard
6
7
8
9
15 16 17 18 19 20 21 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 1 2 3 4 5 6 7 8 9 10 11 12 13 14

present problems of orientation inasmuch as they are closely related to living forms; however, the lack of similarity of the Paleozoic types to those of the post-Paleozoic has caused a wide variation of opinions among several well known investigators.

In this paper an attempt has been made to orient the new ostracod species by comparing certain characteristics of the carapace with those of living species. For instance, in living ostracods the greatest height of the carapace is usually anterior; the adductor scar is usually anterior or migrates forward during ontogeny; and the greatest thickness is posterior. A detailed discussion of the orientation of extinct ostracods by comparison with living forms has been presented by Kesling (1951, p. 94–104).

Collection localities.—Five composite Ledyard and Wanakah shale sections were measured along the line of outcrop from Lake Erie to Seneca Lake. See Text-fig. 1 for generalized columnar section. References to localities indicated in the systematic descriptions are designated by the number which precedes each of the following:

Lake Erie Section

1. Erie County, Hamburg Township, Eighteen Mile Creek, 4.5 miles southwest of Wanakah, N. Y. The upper Wanakah shale outcrops in the stream bank on the northeast side of the bridge.
2. Erie County, Hamburg Township, south branch of Smoke Creek, 0.5 miles north of Windom, N. Y. on Abbott Road. Approximately 0.3 miles west of Abbott Road, trilobite beds of lower Wanakah shale outcrop in the south bank of the stream.
3. Erie County, Hamburg Township, Avery's Creek, 1.5 miles northeast of Wanakah, N. Y. on N. Y. State Route 5. "*Strophalosia*" bed, upper Ledyard shale outcrops in stream bank 30 yards east of highway bridge. Lower few feet of Ledyard not exposed at this locality.

Cazenovia Creek Section

4. Erie County, Elma Township, Cazenovia Creek, 0.4 miles west of Spring Branch, N. Y. Tichenor limestone caps small falls 50 yards east of Northrup Road Bridge. Wanakah and Ledyard shales exposed in banks downstream from the falls.

East Bethany Section

5. Genesee County, Bethany Township, Delaware, Lackawanna, and Western Railroad cut at Francis Road, approximately 3.5 miles west of East Bethany, N. Y. Wanakah and upper Ledyard shales outcrop in the north side of the railroad cut.
6. Genesee County, Bethany Township, 1.8 miles north of Bethany, N. Y. on Center Road. Middle Ledyard shale exposed 20 yards west of the road.
7. Genesee County, Bethany Township, White Creek, 750 yards southwest of the intersection of the Delaware, Lackawanna, and Western Railroad tracks and Transit Road. Centerfield limestone exposed in south bank of White Creek; lower Ledyard shales exposed upstream.

Genesee Valley Section

8. Livingston County, Geneseo Township, south branch of Jaycox Run, 2.5 miles northeast of Geneseo, N. Y. on N. Y. State Route 39. Tichenor limestone caps small falls approximately 0.3 miles west of road. Wanakah and Ledyard members outcrop downstream.

Seneca Lake Section

9. Yates County, Benton Township, Kashong Creek, 7 miles south of Geneva, N. Y. on N. Y. State Route 14. Tichenor limestone caps falls approximately 0.6 miles west of road. Lower half of Ledyard member covered.

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SYSTEMATIC DESCRIPTIONS

Order OSTRACODA Latrielle
Superfamily BEYRICHIACEA
Family AECHMINIDAE Swartz, 1936
Genus AECHMINA Jones & Holl, 1869

AECHMINA MAGNASPINA, n. sp.

Pl. 1, fig. 4

Semiovate in lateral view; hinge line straight, about seven-eights of total length. Cardinal angles slightly obtuse, anterior angle almost 90°. Ventral margin convex; both ends smoothly rounded; greatest protrusion posteriorly about three-fifths of the height from the ventral margin, anteriorly about midheight. Valves convex, surface smooth; overlap relationships not observed. Valve marked by thick spine originating slightly below dorsal margin just anterior to midheight, spine inclined posteriorly (apparent angle of 15° in lateral view); in anterior view spine inclined outward from the vertical (apparent angle of approximately 30°); greater portion of fragile spine hollow.

Relationships.—*Aechmina magnaspina* resembles *Aechmina cuspidata* Jones & Holl, 1896; however, the free margins do not possess the minute spinelets of *A. cuspidata* and the much thicker spine is directed noticeably posteriorly.

This species most closely resembles *Aechmina choanobasota* Kesling, 1952, but differs from it in the attitude of the spine. In lateral view the spine of *A. magnaspina* is slightly anterior of midlength and the base flares less than that of *A. choanobasota;* in anterior view, the shorter spine of *A. magnaspina* forms a more acute angle with the plane of closure of the valves.

Holotype.—NYSM 10718, left valve; length 0.76 mm., height 0.42 mm.; Ledyard shale, locality 7, sample 21 (10 feet above Centerfield-Ledyard contact).

Occurrence.—Lower limy horizon of Ledyard member, rare at locality 7; also occurs in Tichenor shale, rare at localities 5 and 8. Fifteen valves were collected and the tip of the large hollow spine on each of them was missing.

Family BEYRICHIIDAE Jones, 1894
Genus PHLYCTISCAPHA Kesling, 1953

PHLYCTISCAPHA SUBOVATA, n. sp.

Pl. 1, fig. 1–3

Description of male.—Carapace subovate in lateral view, truncated dorsally by a straight hinge line which is about two-thirds of maximum length. Dorsal part of valve slightly flattened, forms faint ridge or slight break in convexity of valve. Cardinal angles obtuse, posterior angle slightly larger than anterior. Ventral margin strongly convex; posterior margin evenly rounded, most protuberant midway between dorsal and ventral margins; anterior margin narrowly rounded, almost angular, greatest anterior protrusion about two-thirds of the maximum height from the ventral margin. Thin marginal ridge on both valves, not as well developed in left valve. Valves almost equal with greatest thickness midway between anterior and posterior ends, flattened slightly toward anterior and posterior free margins; left valve larger than the right, overlaps right on free margins. Surface smooth.

Description of female.—Similar to male in size, overlap of valves, marginal ridge, ornamentation, and hinge line. Pouch in each valve, large swelling on posteroventral portion of valve becoming well defined structure on anteroventral part of valve. Greatest thickness posterior.

Remarks.—No complete female valves were found so the description is based on several large fragments found at the same locality as the males.

Relationships.—This species is closely related to *Phlyctiscapha rockportensis* Kesling, 1953. In lateral view the dorsal margin of *Phlyctiscapha subovata*, n. sp., is almost straight, but in *P. rockportensis* the dorsal part of the valve extends above the hinge line as a noticeable hump. A dorsal view of the males of the two species shows that the greatest thickness of *P. subovata* is midway between the anterior and posterior ends, whereas in *P. rockportensis*, the greatest thickness is well posterior of midlength. *P. subovata* also has a slight flattening on the dorsal margin which is not evident in *P. rockportensis.*

In lateral view the male of *P. subovata* is similar to *Leperditella minuta* Tolmachoff, 1926; however, in dorsal view the hinge line of *L. minuta* is not straight and is more depressed.

Holotype.—NYSM 10717, complete carapace, male; length 1.10 mm., height 0.84 mm., thickness 0.56 mm.; Wanakah shale, locality 1, sample 3 (10–15 feet below Wanakah-Tichenor contact).

Occurrence.— Upper Wanakah shale, rare at localities 1 and 5. Ten complete male carapaces and several fragments of female valves were found at the two localities.

Family KIRKBYIDAE Ulrich & Bassler, 1906
Genus AMPHIZONA Kesling & Copeland, 1954
AMPHIZONA PSEUDOCARINATA, n. sp.
Pl. 1, fig. 5–7

Carapace subquadrate in lateral view. Hinge line straight, approximately three-fourths of maximum length. Cardinal angles obtuse, well defined, anterior angle slightly larger than posterior angle. Ventral margin convex, rounded at extremities; anterior margin more broadly rounded than the posterior. Greatest length about midway between dorsal and ventral margins. Entire surface of valve reticulate. In lateral view two parallel rows of larger than average reticulae form a faint ridge or false carina. Free margins also paralleled by a row of larger reticulae, separated from false carina by a thin strip having smaller reticulae. The more elongate reticulae are frequently separated in the shorter dimension by a thin inconspicuous ridge. Right valve slightly larger than the left, overlaps the left on free margins. Valves slightly convex, in dorsal view slope gently toward margins. Well defined kirkbyan pit located near center of each valve.

Relationships.—This species is closely related to *Amphizona asceta* Kesling & Copeland, 1954; however, the two are easily distinguished by the absence of central ridges, true carinae, and frills on *Amphizona pseudocarinata*.

Holotype.—NYSM 10719, complete carapace; length 0.91 mm., height 0.52 mm., thickness 0.44 mm.; Wanakah shale, locality 7, sample 3 (10–15 feet below Tichenor-Wanakah contact).

Occurrence.—Upper Wanakah shale, rare at locality 7. Eight complete carapaces were collected at the type locality, but additional study specimens were collected from the Tichenor shale at localities 6 and 7.

Family ZYGOBOLBIDAE Ulrich & Bassler, 1923
Genus WELLERIA Ulrich & Bassler, 1923
WELLERIA BISULCATA, n. sp.
Pl. 1, fig. 8–11

Carapace subovate in lateral view. Truncated dorsally by straight hinge line; hinge line three-fourths of maximum length. Cardinal angles well defined, anterior angle larger than the posterior angle. Greatest posterior extension two-thirds height from ventral margin; greatest anterior protuberance midway between dorsal and ventral margins. Greatest height just anterior of center; greatest thickness posterior to well defined median sulcus. Median sulcus commences on dorsal marginal surface, terminates in central part of valve. Anterior sulcus less well defined, commences on dorsal marginal surface and is directed slightly anteriorly, about half as long as median sulcus. The two sulci divide the valve into three distinct lobes; posterior lobe largest and most convex with small prominent spine on dorsal marginal surface. Left valve larger than right. Surface usually covered with fine punctae.

Remarks.—The small prominent spine on the dorsal marginal surface of the posterior lobe is usually undamaged on the valves of the very early moults; however, it is not uncommon to find the larger valves, representing the more mature moults, with one or more of the spines missing. Males and females were not definitely distinguished; there is apparently little difference in the amount of swelling of the posterior lobe in the specimens observed.

Relationships.—The most similar described species appears to be *Welleria obliqua* Ulrich & Bassler, 1923, which is almost twice the size of *Welleria bisulcata* at maturity. *W. obliqua* differs in having sulci of nearly equal length, whereas in *W. bisulcata* the median sulcus is almost twice as long as the anterior sulcus.

W. bisulcata also resembles *Welleria aftonensis* Warthin, 1934, but differs in having a longer median sulcus and the anterior sulcus is directed noticeably forward. In *W. bisulcata* the central lobe or node has a sharp apex near the dorsal margin; in *W. aftonensis* the outline of the central node is well rounded at the dorsal margin.

Holotype.—NYSM 10720, complete carapace; length 1.52 mm., height 1.00 mm., thickness 0.81 mm.; Wanakah member, locality 8, sample 10, trilobite beds (5–10 feet above Ledyard-Wanakah contact).

Occurrence.—Lower Wanakah shale, *Pleurodictyum* and trilobite beds, common at localities 1, 2, 4, 5, and 8. Approximately 200 specimens from 5 localities were studied.

Superfamily CYPRIDACEA
Family GRAPHIADACTYLLIDAE
Kellett, 1936
Genus QUASILLITES Coryell &
Malkin, 1936
QUASILLITES ANGULATUS, n. sp.
Pl. 1, fig. 12–15

Carapace suboblong to subrhomboidal in lateral view. Dorsal margin of left valve slightly convex, rising at posterior end to converge with posterior margin forming smoothly rounded cardinal angle; dorsal margin of right valve convex. Anterior cardinal angle larger than posterior. Posterior margin narrowly curved above the point of greatest protrusion, backward swing below terminating abruptly at ventral margin. Greatest posterior protrusion two-thirds of height from ventral margin. Anterior margin straight to gently curved above the point of greatest anterior protrusion, more broadly rounded below; point of greatest anterior extension one-third of height above ventral margin. Valves strongly convex, greatest thickness one-third length from posterior free margin. Posterior terminal slope steeper and more concave than anterior. Left valve larger than the right, overlaps the right dorsally and on the free margins. Much of external surface ornamented with coarse ridges running almost parallel to dorsal margin; ridges are cross connected by much finer ridges. Ornamentation terminated abruptly at the crest of the prominent anterior ridge which runs parallel to that free margin. Ornamentation fades out gradually on a more gentle anterior slope; less ornamented submedian area. A blunt spine projects posteriorly from the posteroventral part of the prominent ridge, frequently cannot be detected in dorsal view.

Relationships.—Like most species of this genus, *Quasillites angulatus* must be differentiated on the finer points of shape and ornamentation of the carapace. This species is most similar to *Quasillites lobatus* Swartz & Oriel, 1948. In *Q. lobatus* the greatest height is almost midway between ends whereas in *Q. angulatus* it is well anterior. The almost straight dorsoanterior and dorsoposterior free marginal segments intercept the dorsal margin abruptly and therefore more clearly define the cardinal angles of the left valve of *Q. angulatus*. The right valve of this species is very similar to that of *Q. lobatus* but can be distinguished by the much coarser ornamentation and the more convex ventral margin.

Holotype.—NYSM 10721, right valve; length 1.34 mm., height 0.80 mm.; Wanakah member, locality 4, sample 4 (15–20 feet below Wanakah-Tichenor contact).

Occurrence.—Wanakah shale, rare to common at all localities; Ledyard shale, absent at localities 2 and 9, rare at all others. More than 250 valves were collected.

Family ROPOLONELLIDAE Coryell
& Malkin, 1936
Genus PARABUFINA, n. gen.

Carapace subovate to subelongate in lateral view. Left valve larger than the right. Dorsal margin slightly convex. Valve surface granular to finely punctate with prominent ridge near anterior and posterior margins.

Genotype.—Parabufina convexa, n. sp.

Relationships.—This genus is most similar to *Bufina* Coryell and Malkin, 1936, in general outline and in the occasional occurrence of spinelets on the marginal ends. The most obvious difference is the presence of prominent ridges near both ends of *Parabufina* whereas *Bufina* has a prominent crescentic ridge on the anterior end and two blunt spines near the posterior end.

Coley (1954, p. 463) observed that the anterior spines of some species of *Bufina* were thicker and appeared to have coalesced at the bases. He was of the opinion that these thicker spines may have eventually joined to form the ridge near the posterior end of *Parabufina*. After observing several hundred representatives of various species of *Bufina* and *Parabufina* from the Ledyard, Wanakah, and Tichenor shales of western New York the author was not of the same opinion. In dorsal view, the ridges on representatives of *Parabufina* are directed noticeably toward the anterior and posterior. Although a dorsal view of various species of *Bufina* reveals that the posterior spines are directed noticeably forward, the anterior ridge appears to be perpendicular to the hinge line.

Species of *Parabufina* other than those described in this paper are *Parabufina*

craigae (Coley, 1954) and *Parabufina subovalis* (Swartz & Oriel, 1948).

PARABUFINA CONVEXA, n. sp.
Pl. 1, fig. 16–18

Carapace subovate in lateral view. Cardinal angles obtuse, anterior angle larger than posterior. Hinge line straight, two-thirds of the length of the valve. Posterior end narrowly rounded, greatest posterior extension two-thirds of height from ventral margin. Anterior end broadly rounded, most protuberant about two-fifths of height from ventral margin. Ventral margin slightly convex, extremities more rounded. Greatest height one-third of length from anterior free margin. Greatest thickness one-third of length from the posterior free margin. Left valve larger than the right; contact of the valves rabbeted. Surface of valves finely punctate and granular; ornamented by a sharp ridge on both ends of the valve. Posterior ridge slightly more prominent; projects outward and to the rear; anterior ridge projects outward and forward. Some representatives of this species have minute spinelets on the anterior and posterior free margins but others do not.

Relationships.—This species is similar to *Parabufina craigae* (Coley, 1954) but may be differentiated by its convex ventral margin and more sharply crested anterior and posterior ridges.

Holotype.—NYSM 10722, complete carapace; length 0.94 mm., height 0.55 mm., thickness 0.45 mm.; Wanakah member, locality 1, sample 4 (15–20 feet below Tichenor-Wanakah contact).

Occurrence.—Wanakah member, common at localities 1 and 4, rare at localities 2 and 8. Also common in Tichenor shale at locality 9. Approximately 80 specimens were collected for this study.

PARABUFINA POSTRUNCATA, n. sp.
Pl. 1, fig. 19

Carapace subelongate in lateral view. Cardinal angles obtuse, anterior angle larger than posterior. Dorsal margin convex, truncated sharply two-fifths of length from anterior margin; posterior margin more evenly rounded, slight forward swing below point of greatest posterior extension. Greatest posterior extension three-fourths of the height from ventral margin. Anterior end straight, intersected abruptly by straight anterior segments of dorsal and ventral margins forming sharp angles. Greatest height just anterior to midlength. Left valve larger than the right, overlaps the right on the free margins. Surface finely punctate. Prominent ridge rises from the posterior end, almost parallel to posterior margin. Conspicuous ridge also present near the anterior margin, parallel to truncated anterodorsal margin. Hinge line straight. Valves convex.

Relationships.—The distinct angles on the anterior margin of the carapace of this species easily distinguish it from others. *Parabufina postruncata* is also more elongate than any of the other described species of this genus.

Holotype.—NYSM 10723, complete carapace; length 0.91 mm., height 0.42 mm., thickness 0.41 mm.; Wanakah member, locality 1, sample 3 (10–15 feet below Tichenor-Wanakah contact).

Occurrence.—Wanakah member, rare at locality 1. Fourteen complete carapaces were collected.

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EXPLANATION OF PLATE 1

All figures approximately ×26

FIGS. *1–3—Phlyctiscapha subovata*, n. sp. Holotype, NYSM 10717. *1*, Right valve, *2*, left valve, *3*, dorsal view. Wanakah shale, locality 1. (p. 4)

4—Aechmina magnaspina, n. sp. *4*, Left valve of holotype, NYSM 10718. Ledyard shale, locality 7. (p. 4)

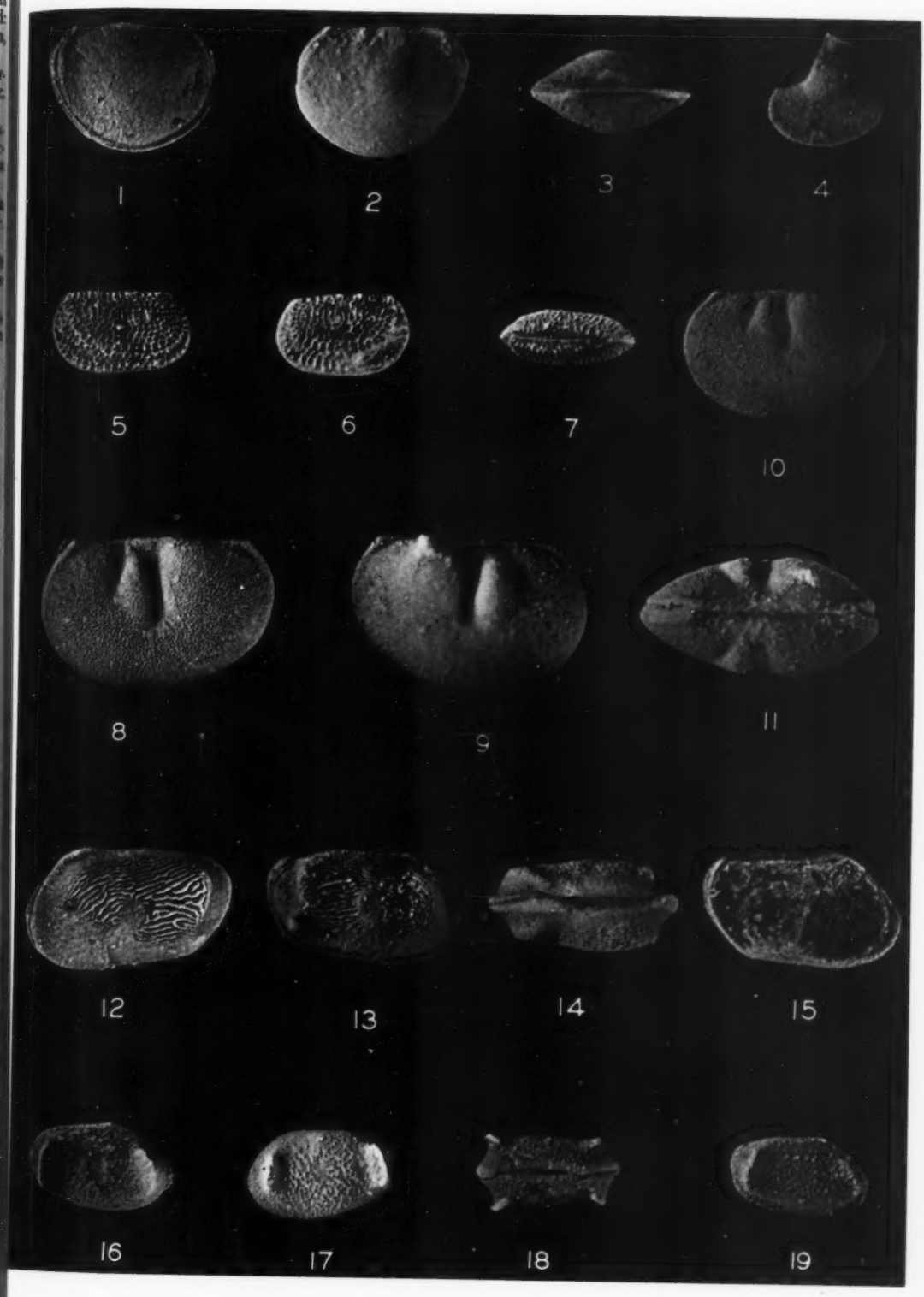
5–7—Amphizona pseudocarinata, n. sp. Holotype, NYSM 10719. *5*, Right valve, *6*, left valve, *7*, dorsal view. Wanakah shale, locality 7. (p. 5)

8–11—Welleria bisulcata, n. sp. *8*, Left valve; *9*, right valve; *10*, left valve; *11*, dorsal view of holotype, NYSM 10720. Wanakah shale, locality 8. (p. 5)

12–15—Quasillites angulatus, n. sp. *12*, Left valve of holotype, USNM 10721; *13*, right valve; *14*, dorsal view; *15*, interior of left valve. Wanakah shale, locality 4. (p. 5)

16–18—Parabufina convexa, n. sp. holotype, NYSM 10722. *16*, Right valve; *17*, left valve; *18*, dorsal view. Wanakah shale, locality 1. (p. 7)

19—Parabufina postruncata, n. sp. *19*, right valve of holotype, NYSM 10723, Wanakah shale, locality 1. (p. 7)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Brooks & Caster, Middle Cambrian phyllocarid, Utah

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 9–14, PL. 2, 6 TEXT-FIG., JANUARY 1956

PSEUDOARCTOLEPIS SHARPI, N. GEN., N. SP. (PHYLLOCARIDA), FROM THE WHEELER SHALE (MIDDLE CAMBRIAN) OF UTAH

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University of Cincinnati

ABSTRACT—A chitinous phyllocarid carapace, *Pseudoarctolepis sharpi*, n. gen., n. sp., is described from the Wheeler shale of Utah. Anterior and posterior dorsal processes of the carapace suggest a common relationship with *Isoxys*, *Tuzoia* and *Dioxycaris*. The new phyllocarid differs significantly in possessing a pair of long, spine-like outgrowths from the sides of the carapace. This feature is believed to be of greater than generic taxonomic value and a new family, Pseudoarctolepidae, is proposed. In order that the probable relation of *Isoxys*, *Tuzoia* and *Dioxycaris* can be indicated by the classification of the Phyllocarida, the family Isoxysidae is established.

INTRODUCTION

THE Wheeler shale of Middle Cambrian age, exposed in the House Range of central western Utah, is widely known for remarkably preserved specimens of *Elrathia kingi* (Meek). The dark shales at the type locality in the Wheeler Amphitheater southeast of Antelope Springs yield trilobites in great profusion, however the known fauna is not large. Walcott (1908, p. 181) lists *Acrothele subsidua* (White), *Agnostus bidens* Meek, *Asaphiscus wheeleri* Meek, *Elrathia* ("*Ptychoparia*") *kingi* (Meek), *Obolus mcconnelli pelias* Walcott, and *Acrotreta attenuata* Meek. Deiss (1938, p. 1132) lists only *Agnostus bidens* (?) Meek, *A.* sp., *Asaphiscus wheeleri* Meek, and *Elrathia kingi* Meek from the type section.

A little-known element of the Middle Cambrian fauna of Utah is the animal which bore the chitinous carapace described and named *Leperditia* (?) *argenta* Walcott (1886, p. 146) (=*Dioxycaris*, Gürich, 1929, p. 36–37). Gürich's genus appears to be related to the new crustacean from the same formation which is the basis of the present paper.

The formation is composed of alternating bands of dark shaly limestone, calcareous shales and black shales; calcareous material predominating in the upper portion. Some horizons resemble in lithology the contemporaneous Burgess shale member of the Mt. Stephen formation of British Columbia, Canada; however fossils comparable to the famed "Burgess shale fauna" have never been reported. The unique preservation of the membranous shield described herein as *Pseudoarctolepis sharpi* is suggestive that remains of other soft-bodied creatures may await discovery in the Wheeler shale.

The specimen was collected from rubble at an exposure near the middle of the type section of the Wheeler shale. The fossil is on a slab 13 cm. by 13 cm. and 7 mm. thick. No other specimens, not even the counterpart, have been discovered. It is through the courtesy of Mr. Byron Sharp, the collector, and Prof. William L. Stokes of the University of Utah that the specimen was presented to the University of Cincinnati Museum for study and description. Charles Blum of Valley Stream, N. Y., recognized the significance of this specimen and was instrumental in its being sent to the authors for study and description.

PRESERVATION

The lithology of the slab of "shale" bearing the fossil is comparable to the lithic characteristics of the "*Marrella* beds" of the Burgess shale. It is a fine textured, slabby, harsh, black, quartzitic siltstone which effervesces weakly to moderately when tested with weak hydrochloric acid. Lami-

EXPLANATION OF PLATE 2

Pseudoarctolepis sharpi, n. gen., n. sp., holotype, ×2.2 Wheeler shale (Middle Cambrian), House Range, Utah.

nations are about 2 mm. thick. Between the natural partings the rock is massive and fractures concoidally. It is within this dense, homogeneous matrix that the fossil occurs.

Because the fossil was embedded in a uniform matrix of silt, it has retained some of its original relief. However, compression of the sediment has produced considerable spreading and distortion. The shield is represented by an internal mold and only traces of carbonized material remain. Two large spines originally were borne on the sides of the shield. The left spine had been broken off with the matrix of the counterpart, however, the nature and outline of the right spine are well displayed. The interior of the basal portion of the spines have been filled with sediment to produce steinkerns. All except the basal portion of both steinkerns had been broken off before discovery. A thin film of carbonaceous material reflects the outline of the right spine.

VERTEBRATE OR ARTHROPOD?

The shield superficially resembles the cephalothoracic shields of some of the Middle Paleozoic arthrodire fish, especially *Arctolepis*, which was endowed with a pair of fixed, long, hollow, lateral projections of the dermal armor in the pectoral region. The oldest known vertebrate remains are from the Harding sandstone of Upper Ordovician age of Colorado and it would be indeed astonishing if the shield from the Middle Cambrian sediments had proved to be the remains of a fish.

The oldest known vertebrates are characterized by an armor of dermal bone. The degradation product of bone is not a carbonaceous film; moreover, the shield from the Wheeler shale is not comparable to the encasing armor that completely surrounded the anterior part of the body of the primitive fish. The most significant evidence that the fossil is not the shield of a primitive vertebrate is that the anterior, ventral and posterior edges of the shield are free. The fossil possesses characteristics, not of primitive fish, but of the shield-bearing "pod shrimp" of the problematical crustacean Order Phyllocarida which flourished in the Paleozoic seas.

DESCRIPTION

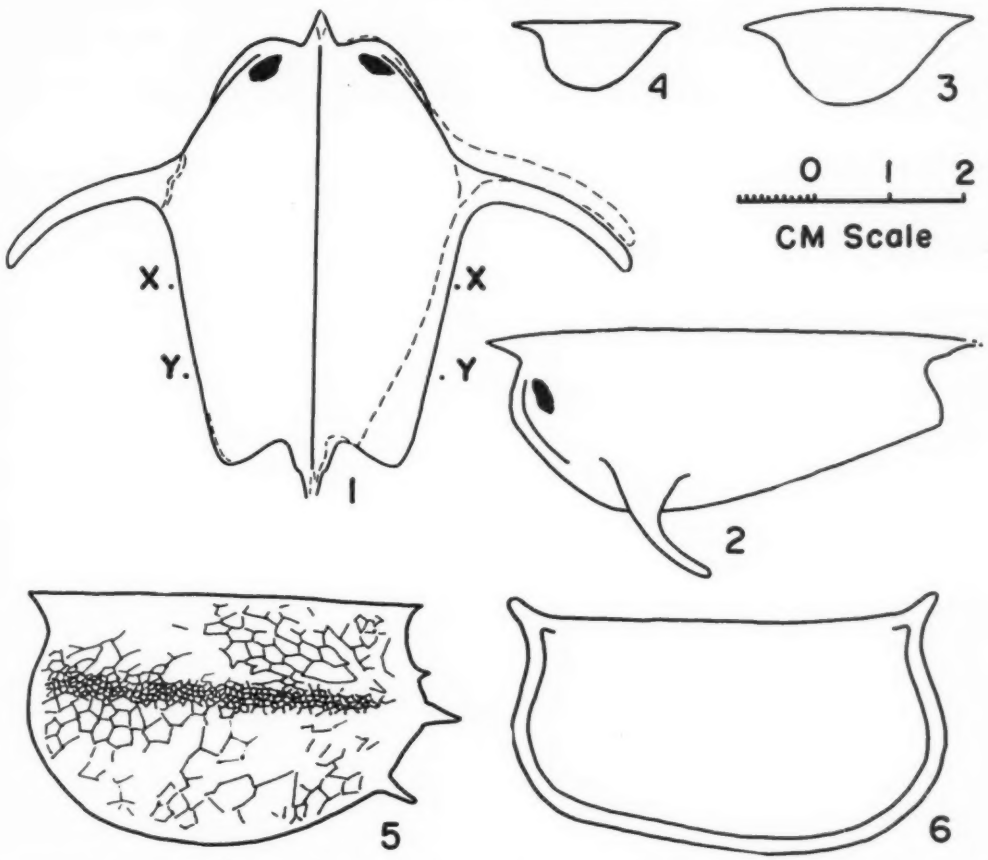
Genus PSEUDOARCTOLEPIS, n. gen.

The single fossil known consists of a cephalic shield or carapace. The preservation indicates that it was thin and unornamented. A rim about 1 mm. wide borders the carapace around the posterior and ventral edges. A margin 2 mm. wide is formed around the anterior by an abrupt bulging of the carapace. Situated on the anterior bulges are a pair of symmetrically located oval-shaped broken patches which may represent the position of compound eyes or more likely, the places of origin of an adductor carapace muscle. Mid-dorsally a line on the internal mold indicates an axis of weakness. That it was an axis of articulation and not a carina is proven by the fact that the carapace has been torn apart at the anterior and posterior extremities of the line. The carapace probably was originally slightly arched dorsally.

The carapace is produced anteriorly in an acute rostrum-like process. Posteriorly there is a corresponding production of the carapace. The most distinguishing characteristic is a pair of long, posteriorly curved, spinous outgrowths from the sides of the carapace. The ventral margins of the carapace are covered by the bases of the spines thus indicating that the spines are not a marginal development as are those of *Tuzoia*, a phyllocarid genus discussed below. The lateral processes are situated at a distance of one third of the length of the carapace from the anterior. Sediment between the dorsal and ventral surfaces of the basal portion of the spines (steinkerns) demonstrates that they were originally hollow (or flesh-filled).

The narrow marginal rim around the ventral and posterior margin of the carapace represents the compressional remains of a narrow marginal doubloure. This is a common feature of fossil malacostracan carapaces.

The generic name was selected to direct attention to the superficial resemblance of the carapace to the cephalothoracic dermal armor of *Arctolepis*, a Lower Devonian arthrodire fish. The genotype is *P. sharpi*.



TEXT-FIG. *1.—Pseudoarctolepis sharpi*, n. gen., n. sp., ×1. Dashes represent deviations of the fossil from the restored bilaterally symmetrical outline.
2—P. sharpi, n. gen., n. sp. A restored lateral view of the left valve of the carapace, ×1.
3—Isoxys chilhoweana Walcott, ×1, Lower Cambrian of Tennessee.
4—I. acutangulus Walcott, ×1, Middle Cambrian at Burgess Pass, British Columbia.
5—Tuzoia burgessensis Resser, ×0.5, Middle Cambrian, Burgess Pass, British Columbia.
6—Dioxycaris argenta (Walcott), ×1, Middle Cambrian, House Range, Utah.

PSEUDOARCTOLEPIS SHARPI, n. sp.
Pl. 2; and Text-fig. 1, 2

Lack of ornamentation, proportional development, and size of the carapace are probably of specific significance. The restored outline of the presently distorted carapace is presented in Text-fig. 1. The original outline is indicated by solid line and distortional deviations are indicated by dashes.

The outline of the rostrum or anterior process of the carapace forms an acute angle of about 50 degrees. Though the tip is unknown, the rostrum is believed, from the projection of the margins, to have been about 3 mm. in length; and it is 3 mm. across at the base. The margin of the rostrum passes into the leading edges of the carapace in an arc (between 75 and 80 degrees) of extremely small radius; about 0.7 mm. The carapace margin is straight for a distance of 3 mm.; then it curves posteriorly through a broad arc and the ventral edges on both sides of the carapace pass beneath the basal protrusions of the lateral apophyses. Posterior to the spines, the ventral margins

are straight. The sides of the carapace decrease in size posteriorly. The exact amount of reduction can not be accurately determined but at the position x-x (Text-fig. 1) the carapace when spread out laterally is believed to have been 3.6 cm. across and 3.1 cm. at the position y-y. The posterior edge originates from the ventral through an arc of 110 degrees which has a radius of 4 mm. The posterior edge is straight for a distance of about 4 mm. It ends at the base of the posterior process. The mid-dorsal posterior process is 6 mm. wide at the base. The process tapers slightly, but at a distance of 5 mm. from the base, it abruptly narrows to a width of 3 mm. Two mm. beyond the point of narrowing, the structure has been broken off; hence the nature of its terminus is unknown. A fracture traverses the base of the process but is of no biological significance.

The total length of the fossil from the tip of the rostrum to the last known portion of the posterior process is 6.4 cm. The maximum length of the sides of the carapace is 5.94 cm. The lateral spines are 2.5 cm. long and the distance across the carapace between the spaces of the spines is 3.9 cm. Because of the posterior curvature of the spines, the maximum spread (as restored with the carapace spread out laterally) is somewhat less than the sum of 2.5+3.9 +2.5 cm. It is 8.4 cm.

Holotype.—Number 31304, Univ. Cincinnati Museum.

Horizon.—Wheeler shale, Middle Cambrian.

Locality.—Type section of the Wheeler shale, Wheeler Amphitheater southeast of Antelope Springs, House Mountains, Utah.

DISCUSSION OF SYSTEMATICS

On the basis of present knowledge of Recent and fossil arthropods, *Pseudoarctolepis* should be classified with the problematical "order" Phyllocarida of the class Crustacea. This category is probably a polyphyletic assemblage.

Phyllocarida was proposed by Packard (1879, p. 128) as an order to include the extant species of primitive Malacostraca of the family Nebaliacea and the Paleozoic "pod shrimp." Recent nębalid Crustacea have the body divided into head, thorax, abdomen [these tagma with 5 (6), 8 and 7 segments respectively] and a furca (=telson with a pair of movable rami). Nebalids differ from typical malacostracans in that they have a carapace adductor muscle, articulated rostrum, more than six abdominal segments and their thoracic appendages are phyllopodous. They have been assigned to the subclass Malacostraca because of a general morphological homology and similar embryological development. A large carapace covers the head and thorax of the nebalids dorsally and laterally but it is not fused with the thoracic segments as in the decapods. As is true with all Malacostraca which have a fold of the cephalic exoskeleton developed into a carapace, the eyes are independent of the carapace. It is believed the broken patches on *Pseudoarctolepis* are muscle scars and not eyes. If these areas represent a pair of sessile compound eyes, a relationship to the notostracan branchiopods, i. e., *Triops*, is indicated.

The ceratiocarids or "pod shrimp" are believed to have possessed most of the morphological characteristics of the nebalids and a classification which implies a phylogenetic relationship is well founded. Some of the shields presently classified with the Phyllocarida may be the carapaces of branchiopods (Jones & Woodward, 1888–1899, p. 4), others such as *Hymenocaris* are allegedly trilobitomorphs (Størmer, 1944, p. 144), and others, e. g., *Discinocaris*, *Peltocaris*, *Aptychopsis*, *Spathiocaris*, *Pholadocaris*, *Ellipsiocaris*, *Cardiocaris* and *Dipterocaris*, are probably aptychi of Paleozoic cephalopods. The latter supposition has been confirmed by the discovery of *Spathiocaris* within the body chamber of a Devonian goniatite (Jones & Woodward, 1888–1899, p. 95). These aptychi are presently classified in the families Discinocaridae and Peltocaridae and assigned to the "order" Phyllocarida (van Straelen & Schmitz, 1934, p. 132–159). There are cases where a form classification serves a useful purpose, but the perpetuation of this misclassification of cephalopod opercula is inexcusable and a flagrant violation of the principles of biological nomenclature.

Because of the many injudicious assignments of fossils to the "order" Phyllocarida, the name has fallen into disrepute. Dismissal

of molluscan opercula will restore a semblance of order. There is a need for a critical restudy of the other "phyllocarids," but for the present, the order can be restored to respectable usefulness as a category incertae sedis for fossils with characteristics suggesting a relationship to the Recent nebalid Crustacea, but whose relationship is not proven, such as *Pseudoarctolepis sharpi* described above. The name Phyllocarida Packard (1879) has priority over the name Archaeostraca Claus (1889) and has become established through usage. The order should be emended to bring it into conformity with the classification employed by neontologists. Thus:

Class Crustacea
Subclass Malacostraca
Series Leptostraca Claus (1889)
Order Nebalida Claus
Order Phyllocarida Packard, emended[1]

Two new families are herein proposed as a result of a study of the relationship of *Pseudoarctolepis sharpi* to *Tuzoia*, *Isoxys* and *Dioxycaris*.

Except for the pair of spine-like outgrowths from the sides of the carapace, *Pseudoarctolepis* (Text-fig. 1, 2) is comparable to some known Lower and Middle Cambrian crustacean carapaces. *Isoxys chilhoweana* Walcott (1890, p. 626) (Text-fig. 3) from the Lower Cambrian of Tennessee, and *I. acutangulus* Walcott (1908, p. 247) (Text-fig. 4) from the Burgess shale of British Columbia, Canada; *Dioxycaris* ("*Leperditia*?") *argenta* (Walcott, 1886) (Gürich, 1929, p. 36–37) (Text-fig. 6) from the Middle Cambrian of Utah, and the many species of *Tuzoia* (Text-fig. 5) from the Lower and Middle Cambrian of North America (Walcott, 1914; Resser, 1930) have carapaces developed anteriorly and posteriorly into dorsal processes. This is a feature that may have developed independently in different phylogenetic races (parallel evolution), but in the absence of counter evidence, relationship seems to be indicated. However, *Pseudoarctolepis sharpi* is sufficiently distinct to merit classification in a separate family.

Isoxys, *Dioxycaris*, and *Tuzoia* were classified in the family Hymenocaridae by Walcott (1914, p. 183, 187). Without stated reason, van Straelen & Schmitz (1934, p. 79, 83, 175) classified *Isoxys* and *Dioxycaris* in the family *Ceratiocaridae*. *Tuzoia* was classified by them with the "Phyllocarida of unknown affinities." Valid members of the family Ceratiocaridae all have a rostrum articulated to the carapace, a feature shared with the Recent nebalids. A rostral process is unknown on species of the family Hymenocaridae. The similarity of the anterior and posterior processes of the carapaces of *Isoxys*, *Dioxycaris* and *Tuzoia* is suggestive of a common relationship and sets them apart from the other phyllocarid types. New families are needed for the Crustacea possessing carapaces with this distinctive feature.

Family PSEUDOARCTOLEPIDAE, n. fam.

Crustacea with mid-dorsal anterior and posterior projections of the carapace and with spine-like outgrowths from the sides. The valves are articulated along the mid-dorsal line. It is believed that a transverse adductor muscle originated near the anterior of the valves. This family is established on *Pseudoarctolepis sharpi*.

Family ISOXYSIDAE, n. fam.

Crustacea with chitinous, dorsally articulated carapaces, the dorsal angles of which are developed into acute processes. Details of the bodies of these carapace-bearing animals are unknown, although *Anomalocaris* (Whiteaves) is allegedly the abdomen of *Tusoia* (Henricksen, 1928, p. 11 and Resser, 1930, p. 6). The name is derived from that of the first named form, *Isoxys chilhoweana* Walcott, 1890.

[1] With the rejection of family Discinocaridae and family Peltocaridae, nine previously proposed families are recognized (van Straelen & Schmitz, 1934). They are: Hymenocaridae, Clark; Nahecaridae, Broili; Ceratiocaridae, Salter: Echinocaridae, Clark; Pephricaridae, van Straelen; Aristozoidae, Gürich; Gürichicaridae, van Straelen; Austricaridae, Glaessner; and Reinocaridae, Clark.

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 15–18, PL. 3, 3 TEXT-FIG., JANUARY 1956

UPPER SILURIAN BRACHIOPODA FROM THE GREAT BASIN[1]

R. H. WAITE
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ABSTRACT—Fossil collections from the upper part of the Laketown dolomite in the Great Basin have yielded several new brachiopod species of probable Upper Silurian age. The new species herein described are *Camarotoechia pahranagatensis, Howellella pauciplicata, Howellella smithi, Protathyris hesperalis* and *Douvillina* (*Mesodouvillina*) *geniculata.*

INTRODUCTION

DURING the field seasons of 1952, 1953 and 1954, collections were made in the Great Basin for the Shell Oil Company. These collections include Upper Silurian fossils which are of importance because almost no fossils of this age have yet been described from the Great Basin (Sweet, 1955, p. 84–85). There have, however, been allusions to Upper Silurian faunas in the Great Basin.

All of the specimens were collected from the Laketown dolomite, along a horizon just a few feet beneath the base of the Sevy dolomite, at two localities: Kings Canyon, Confusion Range, Utah and Pahranagat Range, Nevada. The Laketown dolomite was described by Richardson in 1913 (p. 407, 410) from exposures in Northeastern Utah. Nolan (1935) assigned the Silurian rocks at Gold Hill, Utah to the Laketown dolomite, and Osmond (1954, p. 1915) applied the name to the Silurian rocks at Kings Canyon, Utah. Osmond (1954, p. 1929) cites fossils from the Laketown at Kings Canyon, but he did not record any fossils beneath the Sevy at Pahranagat Pass (1954, p. 1916).

Some of the brachiopods from these localities are morphologically closely allied to European forms, especially species described by Kozlowski (1929) from the Upper Silurian of Poland. *Howellella pauciplicata*, n. sp., and *Protathyris hesperalis*, n. sp., appear to be morphologically very similar to Kozlowski's *H. laeviplicata* and *P. praecursor*, respectively. One might designate these forms by the recurrent term "analogous species." This is a euphemism which means that these species have reached a similar stage of evolution. The analogous species and especially the generic assemblage, including *Douvillina* (*Mesodouvillina*), tend to indicate a late Silurian age for these brachiopods from the Great Basin. Although the evidence is not conclusive, the writer feels justified in assigning this small fauna to the Upper Silurian.

The fauna collected from the upper part of the Laketown dolomite contains only a few species but individual specimens are locally abundant. In addition to the new species described in this paper the following forms have also been collected from the same localities:

Eospirifer sp.
Halysites sp.
Heliolities sp. A
Heliolites sp. B (encrusting form)
Cladopora aff. *C. rectilineata*

The writer is indebted to the Shell Oil Company for the opportunity to collect this fauna and wishes to express his appreciation for their valuable cooperation. He also wishes to express his appreciation to the Museum of Paleontology, University of California at Berkeley, for use of their facilities in the preparation of this manuscript.

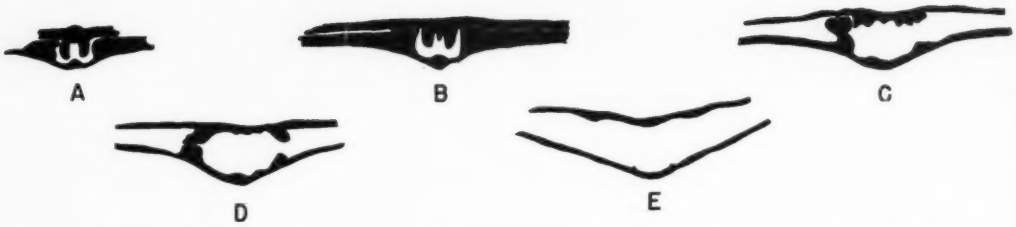
The type specimens from this study are in the University of California Museum of Paleontology. The locality numbers and the type specimen numbers refer to the University of California Museum of Paleontology catalogue.

Collection localities

B-1408—Laketown dolomite, 10 to 15 feet below the base of the Sevy dolomite; Kings Canyon, Millard County, Utah; approximately NE ¼ sec. 11, T. 20 S., R. 16 W.; 100 yards south of U. S. Highway 6.

B-1409—Laketown dolomite, 10 to 25 feet below

[1] Published with permission of the Shell Oil Company.



TEXT-FIG. 1—Serial sections of *Douvillina* (*Mesodouvillina*) *geniculata*, n. sp. (ca. ×4). Pedicle valve below. Distance from posterior tip of pedicle beak: A, 0.4 mm.; B, 0.5 mm.; C, 0.8 mm.; D, 1.1 mm.; E, 3.0 mm.

the Sevy dolomite; Pahranagat Range, Lincoln County, Nevada; approximately SE ¼ sec. 31, T. 6 S., R. 59 E.; 2 miles south of Nevada State Highway 25.

SYSTEMATIC PALEONTOLOGY

Phylum BRACHIOPODA

Class ARTICULATA

Superfamily STROPHOMENACEA

Genus DOUVILLINA Oehlert, 1887, emend.

Subgenus DOUVILLINA (MESODOUVILLINA) Williams, 1950

DOUVILLINA (MESODOUVILLINA) GENICULATA n. sp.

Text-fig. 1; Pl. 3, fig. 20–24

Exterior.—Outline semi-elliptical, mucronate; profile geniculate, concavo-convex; pedicle interarea apsacline; pseudodeltidium convex, not entirely closing delthyrium; brachial interarea anacline; chilidium convex; ornamentation parvicostellate.

Pedicle interior.—Hinge line partially denticulate; dental plates absent; pseudodeltidium supported by ventral process; diductor scars bounded by short lateral ridges.

Brachial interior.—Cardinal process lobes incipiently disjunct; small septum or prolongation of chilidium present between cardinal process lobes; socket plates short; median ridge low.

The average size of 22 specimens is: length 14 mm., width 22 mm., thickness 2.5 mm.

Discussion.—This species differs from *D.* (*M.*) *newsomensis* (Foerste) in that it is more geniculate and does not posses coarse internal granules. It differs from *D.* (*M.*) *subinterstrialis seretensis* (Kozlowski) in that it is not triangular in outline and is more strongly geniculate. Nomenclature after Williams (1953).

Holotype.—UCMP 14760.

Occurrence.—B-1408.

Superfamily RHYNCHONELLACEA

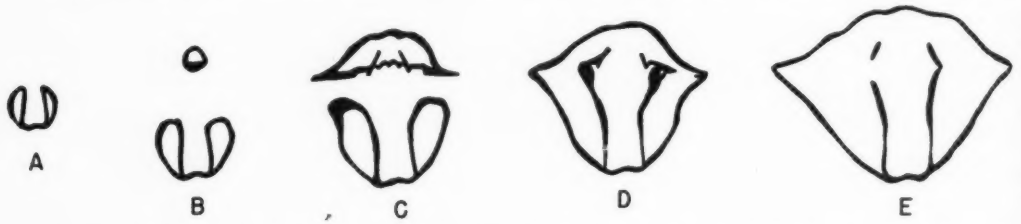
Genus CAMAROTOECHIA Hall & Clarke, 1892

CAMAROTOECHIA PAHRANAGATENSIS n. sp.

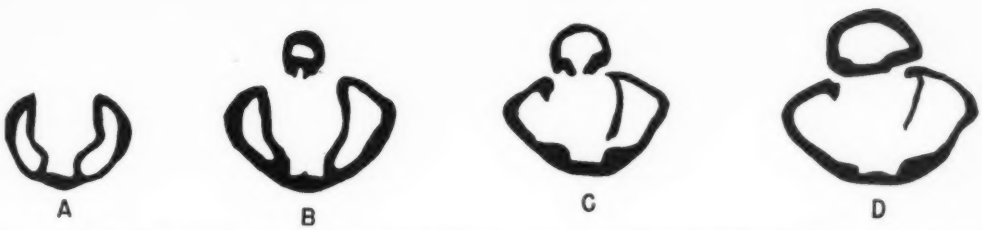
Pl. 3, fig. 1–5

Exterior.—Outline subelliptical; shell biconvex; pedicle beak erect, foramen mesothyrid; pedicle sulcus begins about 6 mm. from beak and bears three or, more commonly, four plications; each lateral pedicle slope bears from six to eight sharply angular plications; brachial fold begins about 5 mm. from beak and bears four or five plications; each lateral brachial slope bears from five to seven plications.

Brachial interior.—No cardinal process; hinge plate divided, upheld by supporting plates; supporting plates rest on median



TEXT-FIG. 2—Serial sections of *Howellella pauciplicata*, n. sp. (ca. ×4). Pedicle valve below. Distance from posterior tip of pedicle beak: A, 0.6 mm.; B, 1.1 mm.; C, 1.8 mm.; D, 1.9 mm.; E, 2.4 mm.



TEXT-FIG. 3—Serial sections of *Protathyris hesperalis* n. sp. (ca. ×4). Pedicle valve below. Distance from posterior tip of pedicle beak: A, 1.0 mm.; B, 1.3 mm.; C, 1.6 mm.; D, 1.7. mm.

septum, forming a small cruralium.

Pedicle interior.—Dental plates short; no median septum.

The average dimensions of 47 specimens are: length 15.7 mm., width 17.1 mm., thickness 10.8 mm.

Discussion.—This species is similar to *C. filistriata* Amsden but is larger and has fewer plications on fold and sulcus. The cruralium in *C. pahranagatensis* is better developed than in *C. filistriata* Amsden (1951) or in *C. cedarensis* Amsden (1949). Dr. Amsden has kindly brought to the writer's attention the fact that the genotype of *Camarotoechia* has a small plate covering the cruralium. He further comments that the species assigned to "*Camarotoechia*" from the Brownsport and Henryhouse formations appear to be congeneric with the species described above but feels that they merit a new generic assignment. Dr. Amsden implies that a new generic description should await a complete study of all Silurian rhynchonellids. In keeping with these suggestions this species is tentatively assigned to the genus *Camarotoechia*.

Holotype.—UCMP 14816.

Occurrence.—B-1408, B-1409.

Superfamily SPIRIFERACEA
Genus HOWELLELLA Kozlowski, 1946
HOWELLELLA PAUCIPLICATA n. sp.
Text-fig. 2; Pl. 3, fig. 6–10

Exterior.—Outline subelliptical; shell biconvex, pedicle valve having greatest convexity; hinge line straight, shorter than greatest width of shell; pedicle beak slightly hooked; pedicle palintrope well developed, apsacline; cardinal margins broadly rounded; delthyrium open, triangular; brachial interarea narrow, anacline; pedicle valve bears a shallow sulcus beginning at the beak and becoming broader anteriorly, sulcus bounded by a low, rounded costa on each side; brachial valve bears a low, broad fold bounded by narrow, ill-defined sulci; lateral slopes generally smooth but occasionally bear one or, rarely, even two obscure costae; anterior commissure uniplicate to parasulcate; surface of well preserved specimens show regularly-spaced, concentric lamellae and occasionally exhibit faint spines.

Pedicle interior.—Dental plates short, extending dorsally above the palintrope to form low, blade-like ridges, normal to the palintrope, bounding the delthyrium laterally (deltidial plates?); no median septum present.

Brachial interior.—Cardinal process an obscure roughened excrescence; spiralia not observed.

The average size of 85 specimens is as follows: width 9 mm., length 7.5 mm., thickness 5.3 mm. The smallest specimen is only 2.4 mm. wide and the largest specimen is 12.5 mm. wide.

Discussion.—This species is morphologically similar to *H. laeviplicata* (Kozlowski) but it is smaller and has fewer costate.

Holotype.—UCMP 14745.

Occurrence.—B-1408.

HOWELLELLA SMITHI n. sp.
Pl. 3, fig. 16–19

Exterior.—Outline subelliptical; hinge line straight, shorter than greatest width of shell; shell biconvex, pedicle valve with greatest convexity; pedicle interarea well developed, apsacline, bearing laterally directed striae; brachial interarea orthocline to slightly anacline; pedicle valve with a well defined sulcus beginning at the beak; brachial valve with a flat-topped or even faintly sulcate fold; costae low, rounded, two or three on each side of brachial valve, three or four on each side of pedicle valve; ornamentation other than concentric growth

lines not observed (all specimens silicified).

Pedicle interior.—Dental plates short, anterior edges highly concave, extending above the palintrope as in *H. pauciplicata;* no median septum.

Brachial interior.—As in *H. pauciplicata.*

All four specimens are approximately the same size. The holotype is 14.8 mm. long (incomplete), 16.9 mm. wide, and 11.9 mm. thick.

Discussion.—This species differs from *H. pauciplicata* in its larger size and its more numerous and distinct costae. It differs from *H. henryhousensis* Amsden in its larger size and less prominent costae. This species was named in honor of Mr. Walter L. Smith of the Shell Oil Company.

Holotype.—UCMP 14746.

Occurrence.—B-1409.

Superfamily ROSTROSPIRACEA
Genus PROTATHYRIS Kozlowski, 1929
PROTATHYRIS HESPERALIS n. sp.
Text-fig. 3; Pl. 3, fig. 11–15

Exterior.—Outline subcircular in young individuals, subpentagonal in largest specimens; biconvex, pedicle valve slightly deeper; hinge line submegathyrid to megathyrid; length and width almost equal; pedicle beak rostrate; narrow deltidial plates concealed by the short brachial beak; young individuals without fold or sulcus, larger specimens have a faint brachial sulcus and a more pronounced but still weak pedicle sulcus; anterior commissure rectimarginate to slightly uniplicate; ornamentation other than faint growth lines not observed (all specimens silicified).

Pedicle interior.—Dental plates short, stout, limited to the umbonal region; no median septum; musculature an impressed groove in the umbonal region, bifurcating anterior to the hinge line into two weak grooves separated by a low, rounded ridge.

Brachial interior.—Hinge plate triangular, undivided, with a foramen at the posterior edge, bounded laterally by well developed dental sockets; no median septum; brachidia athyroid, six or seven loosely coiled, laterally directed spires in each spiralium; jugum not observed.

Of about 125 specimens the smallest specimen is 2.4 mm. long, 2.3 mm. wide, and 1.1 mm. thick; the largest specimen is 12.1 mm. long, 12.3 mm. wide, and 7.7 mm. thick. The average length of the specimens at hand is 9 mm.

Discussion.—This species is similar to *P. praecursor* Kozlowski but differs in that it is smaller and the hinge plate is less lobate and less concave.

Holotype.—14794.

Occurrence.—B-1409.

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EXPLANATION OF PLATE 3

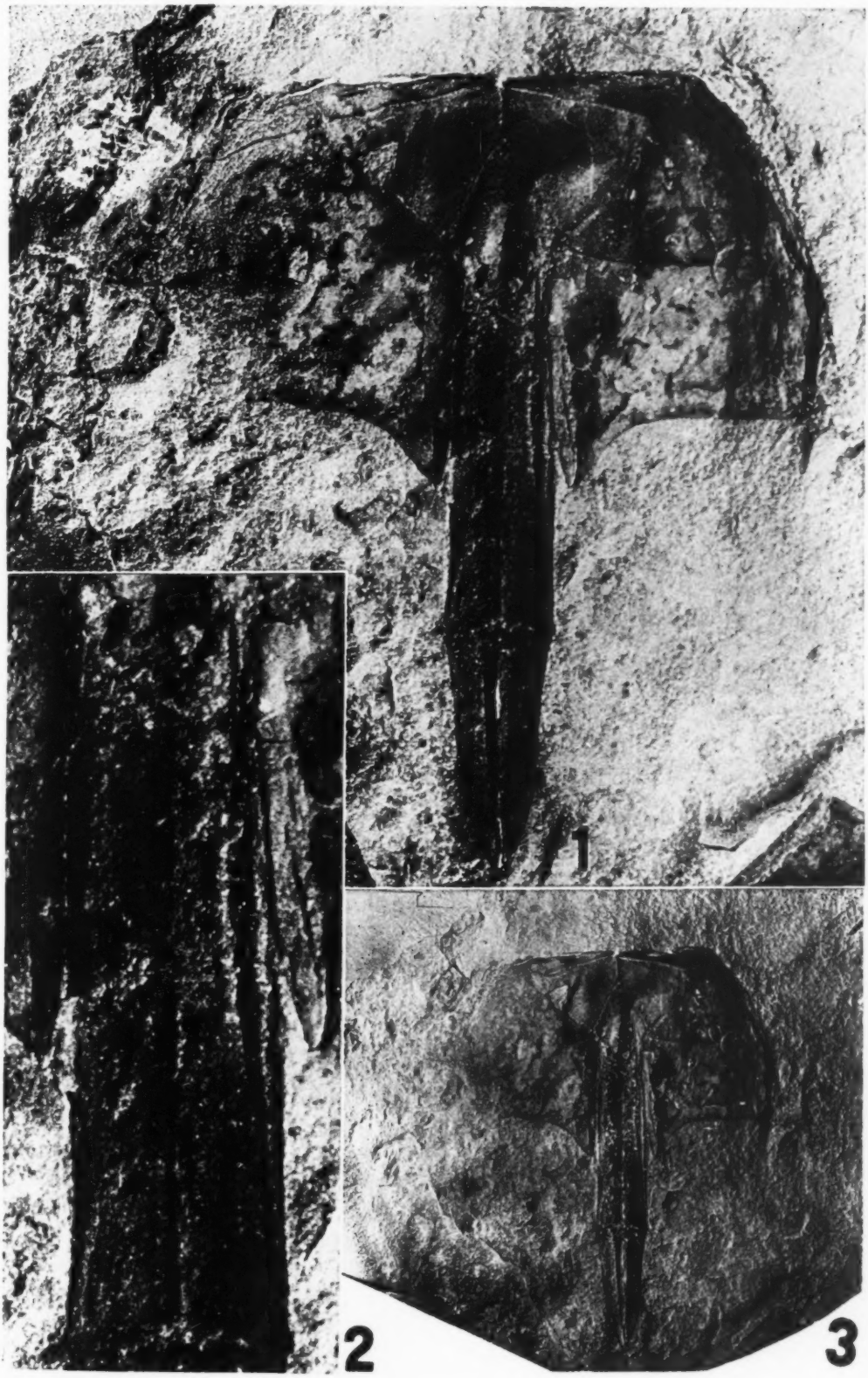
FIG. *1–5—Camarotoechia pahranagatensis* n. sp. *1–4,* Brachial, pedicle, anterior and lateral views of holotype ×1.5. UCMP 14816. *5,* Interior of a portion of another specimen showing cruralium ×4. (p. 16)

6–10—Howellella pauciplicata, n. sp. *6–9,* Brachial, pedicle, anterior and posterior views of holotype ×1.5. UCMP 14745. *10,* Internal view of hinge area of another specimen ×3. (p. 17)

11–15—Protathyris hesperalis n. sp. *11–13,* Brachial, anterior and lateral views of the slightly damaged holotype ×2. UCMP 14794. *14,* Interior of brachial valve of another specimen ×3.5. *15,* Interior of pedicle valve of another specimen ×3. (p. 18)

16–19—Howellella smithi, n. sp. *16–18,* Brachial, pedicle and posterior views of holotype ×1.5. UCMP 14746. *19,* Interior of pedicle valve of another specimen ×1.5. (p. 17)

20–24—Douvillina (Mesodouvillina) geniculata, n. sp. *20, 22,* Brachial and lateral views of holotype ×1.5. UCMP 14760. *21,* Pedicle view of another specimen ×1.5. *23,* Enlargement of part of fig. 20 ×4.7. *24,* Part of brachial interior showing cardinal process lobes ×5. (p. 16)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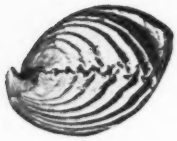
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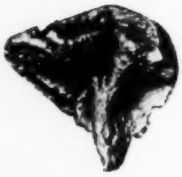
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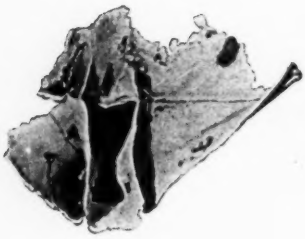
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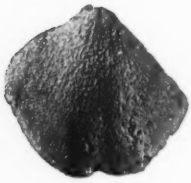
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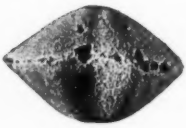
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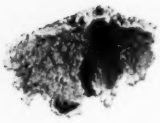
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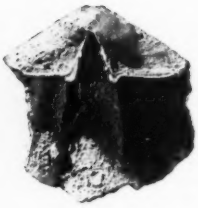
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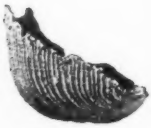
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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 19–28, PL. 4, 1 TEXT-FIG., JANUARY 1956

SOME NOTES ON THE GENUS *DOLICHOPTERUS* HALL

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University of Cincinnati and Tulsa, Oklahoma

ABSTRACT—An exceptionally well-preserved eurypterid operculum ("type A") from the classic Upper Silurian "Bertie" waterlime of Jerusalem Hill, Herkimer County, New York, proves to be specifically new: *Dolichopterus jewetti* Caster and Kjellesvig-Waering. The operculum establishes the presence of three pairs of lateral plates united by sutures. The presence of the proximal pair of opercular plates had not been previously established. A new European eurypterid species from the famous Oesel Silurian beds is named *Dolichopterus størmeri* and another form from the "Bertie" waterlime of New York is designated as *Dolichopterus herkimerensis*.

INTRODUCTION

THE eurypterid operculum on which this study is based is a part of the famous old Jewett Collection of fossils which Ezra Cornell purchased for his University long before its doors were opened. It turned up by accident in one of the great public collections, and is now by arrangement returned to Cornell University. The specimen still carries in faded ink Col. Jewett's (?) notation "New crustacean! Pentamerus limestone, Jerusalem Hill." It is one of the best preserved eurypterid genital plates from the New York area. Happily, after all these years (probably close to a century) and the thorough winnowing of the New York eurypterid harvest by paleontologists, Jewett's discovery remains new to science, and a most revealing morphologic document as well. The name *Dolichopterus jewetti* memorializes the pioneer paleontologic collecting by Col. Jewett.

The best known eurypterid faunas of North America, and among the best preserved anywhere, are those of the Upper Silurian (Cayugan) "Bertie" waterlime (dolomite) of Erie County in western New York and Herkimer County in central New York. These two sites are approximately two hundred miles apart and despite lithic similarity and presumed time equivalence carry different eurypterid assemblages. As will be seen by the list, below, the genera are much the same in the two sites, but the species are mostly distinct. Clarke & Reudemann (1912, p. 170) report the possibility that *Eurypterus remipes* DeKay, a common species in the Herkimer area, may occur in the Buffalo fauna. They also report the commingling of this species with the characteristically western species *E. lacustris* Harlan in the intervening New York counties. It is a distinct handicap that none of these extraterritorial records has been documented; hence the reports are not readily evaluated.

The complete list of eurypterids now known from the lower Bertie of New York State is as follows:

Buffalo District

Carcinosoma scorpionis (Grote & Pitt)
Dolichopterus macrocherirus Hall
Dolichopterus siluriceps Clarke & Ruedemann
Eurypterus dekayi Hall
Eurypterus lacustris Harlan
Eurypterus pustulosus Hall
Pterygotus cobbi Hall
Pterygotus cummingsi Grote & Pitt*
Pterygotus grandis (Pohlman)

* *Pterygotus cummingsi* Grote and Pitt 1877 has clear priority over *Pterygotus buffaloensis* Pohlman 1881.

EXPLANATION OF PLATE 4

FIG. *1–3*—*Dolichopterus jewetti*, n. sp. *1*, Holotype operculum, ×2. *2*, Detail of the median process, showing details of the lateral lobes, ×4. *3*, Same specimen photographed with a coating of ammonium chloride in order better to show the contour, ×1. Imprints of several ostracodes (*Leperditia?*) show through the left side of the eurypterid integument. In reality the median and posterior opercular plates were unornamented in life. Scales are present on the anterior half of the front pair of plates. (p. 22)

Herkimer District

Brachyopterus? testudineus Clarke & Ruedemann
Dolichopterus herkimerensis Caster & Kjellesvig-Waering, n. sp.
Dolichopterus jewetti Caster & Kjellesvig-Waering, n. sp.
Eurypterus remipes DeKay
Hughmilleria trigona (Ruedemann)
Pterygotus macrophthalmus Hall
Pterygotus juvenis Clarke & Ruedemann

All students of the two eurypterid faunas and the Bertie stratigraphy have thus far worked on the assumption that the two occurrences were contemporaneous. This seems still to be the view of New York's paleontology division (letter Donald Fisher to Caster, Dec. 16, 1954). The two sites differ only in biofacies; the lithofacies appears to be closely similar.

The faunal differences have been accounted for by geographic isolation or other obscure environmental factors. Thus Clarke & Ruedemann (1912, p. 9–10) argued for coeval geographic speciation in two isolated "pools" of the Bertie sea. The splendid preservation and frequent occurrence of well articulated specimens in both "pools" argued for death in situ, and only casual disturbance after death (essentially biocoenoses). Precisely how the isolation was achieved, in view of their reported comminglings in the intervening areas, and the seeming continuousness of the limestone between the two sites, remains obscure. Marjorie O'Connell (1916, p. 106–118) developed the fresh-water thesis with respect to the eurypterid environment, and visualized the occurrence of the two faunas in the Bertie waterlime as separate river mouths. Apparently two main rivers flow southward from an "Atlantica" into the Cuyugan sea, each with its autochthonous eurypterid fauna. The intervening comminglings would seem to reflect the mouths of intervening streams where geographic ranges were overlapping. O'Connell's views would make the occurrences thanatocoenoses. How two rivers, so close together, at the same latitude and elevation, and apparently having the same physical environmental conditions, can serve to account for the differences in the two faunas is indeed difficult to explain.

There is no particularly good reason to resume the long-standing debate concerning the ecology of the eurypterids. Where such extreme positions are so stalwartly and uncompromisingly maintained, truth often lies in the middle ground. Eurypterid history was marine in Ordovician times so far as the record has revealed. Apparently these animals dwelt in the shelly facies of the epeiric sea, and may have preferred shoal waters. In Silurian times their preferred setting seems to have shifted to the more specialized environments of the sea margins. In view of their arachnid and merostomaceous kinship, it would not be surprising if they exhibited wide ecologic tolerances, and especially in the nearshore setting where the ecologic extremes exist in close proximity. There seems now no reason to doubt that the eurypterids lived in the Cayugan seas which were recurrently hypersaline; nor does their demise seemingly correlate with the salines. Neither the sediments nor the condition of the eurypterid integuments argue for stream contamination in the most famous eurypterid localities of New York State. To what degree the Cayugan eurypterids may have invaded estuaries, or tolerated fresh water, the Cayugan record seems not to give an answer.

According to Donald Fisher (letter to Caster, Dec. 16, 1954) the stratigraphy of the "Bertie" unit of the Upper Silurian has been traced in detail across New York State from the Buffalo region to the Herkimer area. The lithology seems to be constant throughout the two hundred miles, and the detailed stratigraphic sequence monotonously similar from section to section. At any particular profile the lithologic sequence seems to be as follows: (oldest on the bottom)

1. (Akron-Cobleskill) crystalline limestone
   .....minor hiatus.....
2. (Williamsville or upper Bertie) waterlime-cement beds
3. (Scajauquada or middle Bertie) dark shales
4. (Fiddler's Green or lower Bertie) ribbon dolomite (eurypterid faunas)
5. (Camillus) gypsiferous black shales with a medial limestone

With the exception of the top unit of

crystalline limestone, all of these units have been shown by Fisher & Rickard (1953) to grade eastward into arsenopyritic Brayman dark shales. These are a more shoreward facies, and prior to the work of Fisher & Rickard had been considered as a late Ordovician "soil" horizon (Ruedemann, 1930, e.g.). The transition into the Brayman facies is progressively further east the higher in the above column, 2–5, one proceeds; this conforms to the usual pattern of transgressive sedimentation. The names were for the most part applied before the lateral facies shift was understood.

Once the lateral facies change from west to east was established, the absolute contemporaneity of individual stratigraphic units from its western expression to its eastern becomes suspect. In spite of the undoubted coetaneousness of the lithofacies expressions across the strike belts of New York State from west toward the east, it is quite unlikely that this tracing establishes contemporaneity of the lithic record. It seems more probable that heterochronous facies, i.e., magnafacies (Caster, 1934) have at least in part been misconstrued for isochronous lithic expressions.

Here our concern is only with the lower Bertie unit (Fiddler's Green). Fisher & Rickard (1953) show the lower Bertie to transgress eastward into the Brayman facies (magnafacies). East of Herkimer County, between Cherry Valley and Carlisle, successively higher beds of the Fiddler's Green pass into the Brayman facies, and from Carlisle eastward the unit has completely assumed the Brayman expression. There is no reason to suppose that this phenomenon of eastward transgression does not characterize the entire Fiddler's Green lime sequence; hence it would have been deposited considerably earlier in Cayugan time in the Buffalo area than two hundred miles further east. Accordingly, the Buffalo eurypteroids were older by the amount of time it required for the lime facies to transgress to Herkimer County. The time was sufficient for speciation to achieve the differences noted in the two areas.

On the other hand, when considering the relative age of the two deposits, one must have more information on the sedimentation of the upper part of the Fiddler's Green unit. What is the precise nature of the contact with the overlying shale (referred to the Scajauquada by Fisher)? Is the contact a lithic gradation or is it diastemic? The shale appears to be a westward *regression* which carried the eastern facies (modified Brayman) temporarily far to the west. This may have no bearing on the relative age of the two eurypterid occurrences. On the other hand, if the lime facies grades into the shale above, then it may have been regressional also, and the Herkimer fauna older than the Buffalo one. Unfortunately the species differences between the two faunules (parvafacies expressions) are insufficient and older phylogenetic data too few to answer the question. However, in the light of present stratigraphic information it seems most unlikely that the two faunas were contemporaries; hence the differences are more understandable.

The reported interminglings of the two faunas in the areas between the Herkimer and Buffalo occurrences would be better understood as falling between the two sites in time, and thus would be intermediate parvafacies expressions of the same magnafacies belt. The problem would seem to be much the same as that which obscured the Devonian stratigraphic relations in New York State for so many years. Throughout the Penn-York Embayment of Devonian-Mississippian time facies planes were misconstrued for timeplanes by the older school of stratigraphers. Their "pancake" geology made almost incomprehensible the supposedly coeval lateral changes of marine faunas across the regressive deposit.

Differential rates of mutation and consequent evolution would adequately account for the presumably long range of *Eurypterus remipes* relative to that of the other eurypterids of the "Bertie" faunas. Clarke & Ruedemann (1912, p. 170) report this conservative species (but do not describe or figure the specimens) from the Rondout limestones of Seneca County, New York. The Rondout limestone next overlies the Akron-Cobleskill.

ACKNOWLEDGMENTS

We are grateful to the officers of the United States National Museum for calling this specimen to our attention and to the Geology Department of Cornell University

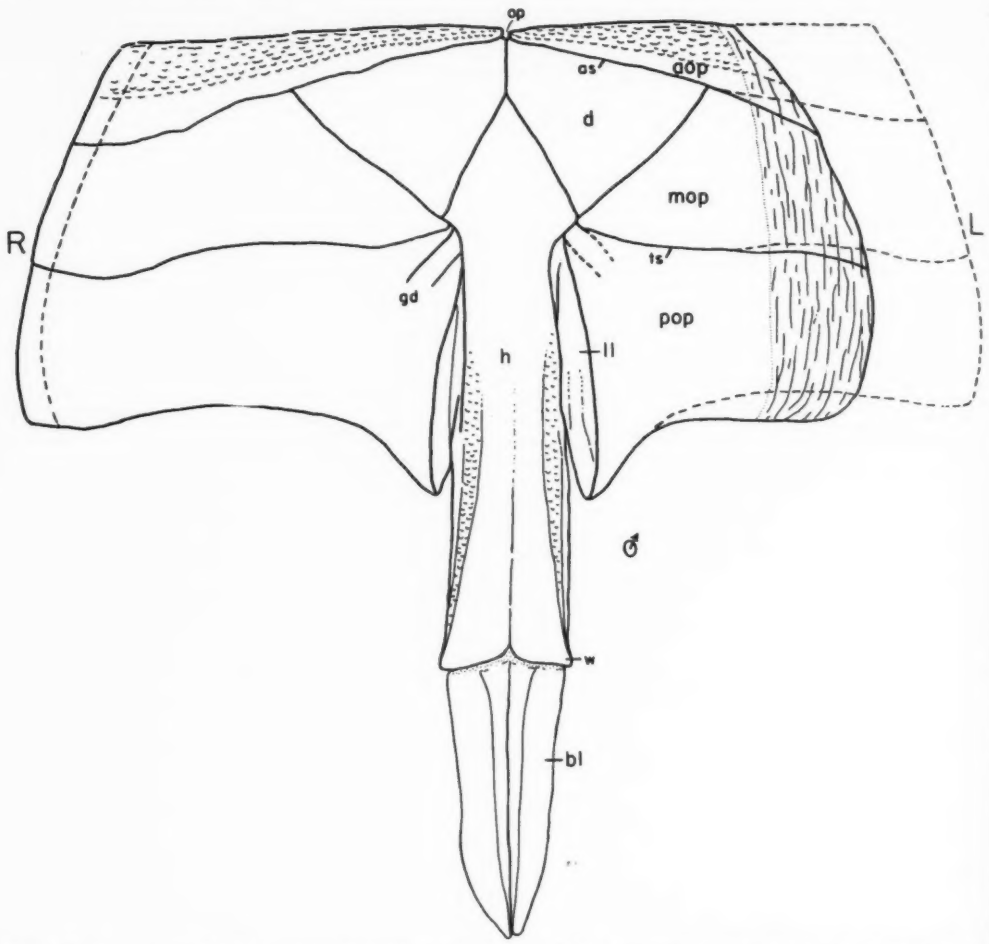

FIG. 1.—Holotype of *Dolichopterus jewetti*, n. gen., n. sp. Solid lines represent the fossil; broken lines the restored outline. *aop*, anterior opercular plates (new); *as*, anterior suture; *bl*, blades of the stiletto; *d*, "deltoidal" plates; *gd*, internal tubules; *h*, single basal segment of the genital process; *ll*, lateral lobes (sutured to posterior opercular plates); *mop*, median opercular plates (formerly considered anterior); *op*, open contact of the anterior opercular plates; *pop*, posterior opercular plates; *ts*, transverse suture; *w*, wings. Traced from a photograph of the holotype.

for the permission to study it. Mr. Harold K. Brooks, Curator of the University of Cincinnati Museum, aided with the photography.

SYSTEMATICS

Family DOLICHOPTERIDAE Kjellesvig-Waering & Størmer, 1952

Genus *Dolichopterus* Hall, 1859

DOLICHOPTERUS JEWETTI n. sp.

Pl. 4; Text-fig. 1

The holotype consists of an unusually well-preserved male* operculum with attached median process. The over-all aspect is that of a narrow individual; this is, how-

* Although sexual dimorphism of the Eurypterida has been recognized for many years, there has been no final consensus as to the sexing of the two forms. We follow here the arguments advanced by Størmer (1933) which was a revival and amplification of Gaskell's (1908) heterodox views on the matter. According to the Gaskell-Størmer interpretation, the present form, which is the "type A" operculum, presumably pertained to a male. Much further study is needed before the matter is definitively settled.

ever, in large part a preservational illusion, the left side* having been laterally compressed. The median process is very stout and long in keeping with the Dolichopteridae, wherein it usually attains the third abdominal plate.

The apparent proportions of the operculum are width to length as four to one; however, when adjustment is made for slight flattening of the right side and the lateral compression of the left. the proportions in life may well have been as five to one. In Text-fig. 1 the outline of the holotype is shown in solid line and the restored margins in broken line.

The front margin is rectilinear. The integumentary material of the operculum is preserved along this line for 38 mm.; of this 15.5 mm. pertains to the left side, and 22.5 to the right. Projecting the curvature of the right margin toward the front would make the right half of the front margin measure 27 mm.; doing the same on the left would yield 19 mm. It would appear that lateral crumpling has reduced the latter by at least 6 mm., and flattening may have expanded the right side by 2 mm.; thus, the lifetime width of the front opercular margin was probably close to 50 mm.

The sides of the operculum are arcuate, but it would appear that only the right side approximates the true arc. Apparently the sides converged a bit more proximally than distally. The maximum width of the operculum comes at the lateral termini of the transverse suture (*ts*) where it measures 54.7 mm. on the specimen. By the same kind of adjustment as was made for the front margin, this figure becomes 59 mm. for the undistorted maximum width. The rear corners of the operculum are not clearly shown, but they appear to have been rounded; and the width is estimated at 58 mm.

The posterior margins of the opercular plates are broadly concave. They are produced into prominent wings (*w*) or horns adjacent to the median process.

The over-all axial length of the operculum is 58.5 mm.; the length of the opercular plate area, exclusive of the horns is 26 mm; inclusive of the horns, 30 mm.

* Right and left refer to the living organism, not to the fossil as observed by the paleontologist.

The posterior paired plates (*pop*) make up nearly half the non-process area of the operculum. In front they are united by the transverse suture (*ts*) to the median pair of plates (*mop*). The transverse suture is very well developed, and leaves no doubt as to the distinctness of the plates it separates. It is likely that the trend of this suture on the right side is less deformed. Inspection shows that instead of swinging rearward as the lateral margin is approached on the crushed left side, on the less modified right it swings forward.

The inner margins of the rear plates are delimited by lanceolate plates (*ll*) or lobes. These appear in life to have overlapped the dorsal margins of the median process. The left side shows a suture (break) between the lanceolate plates and the main opercular plate; on the right this suture is limbate. The suture extends from the tips of the wings to the posterior median angle of the posterior plates.

In the proximal median angles of the posterior opercular plates, adjacent to the place of expansion of the main shaft of the process into its proximal halberd, there are preserved the imprints of two tubular conduits (*gd*) which lay dorsad of the opercular surface. The conduits trend in an undulatory course for a couple of millimeters postlaterally. These are presumed to be the structures called seminal vesicles (or oviducts) by eurypterid students. They do not appear to lead to external apertures, none of which have been observed on the operculum. If the process served as a conduit of genital products, no doubt the ducts lead into its internal axial region.

The median opercular plates (*mop*) (commonly called anterior) are in transverse series with the deltoidal plates (*d*) to which they are united by oblique sutures. They are subtrigonal in outline. The oblique or "diagonal" sutures extend anterolaterally from the apices of the lateral wings of the process halberd. These sutures are very distinct. The front margin of the median plates, and of the deltoidals, is again a very distinct suture which separates them from the pair of anterior marginal plates (*aop*).

The deltoidal plates (*d*) bound the anterior margin of the process hastation, from

which they are separated by a suture. They meet anteriorly on the saggital line, also by suture. They are thus quadrilaterals rather than triangles or pentagons as in some other eurypterids.

The front margin of the operculum is occupied by two triangular plates (*aop*) which taper to rounded apices at the median lines, where they are in contact, but appear not to have been united by suture. Posteriorly they are firmly sutured to the median opercular plates (*mop*) and the deltoids (*d*). The suture-line is depressed and the adjacent plate margins elevated in a low border ridge. The front half of the anterior plates is covered by imbricate scale-like ornament which grades into transverse wrinkles near the proximal margin and the axis. The posterior half of these plates is smooth, and resembles in this respect the other opercular plates. The scale-like ornament is rather sharply delimited posteriorly.

The lateral areas of the opercular plates are now axially wrinkled; especially so the left side. The zone of wrinkling is sharply and arcuately defined. This line may correspond to a sharp transition in the thickness of the chitin of the opercular flaps. The wrinkling itself appears to be due to lateral deformation of the fossil. The central part of the operculum is broadly arched, presumably in life attitude. The area of the hastation of the process and the adjacent deltoidal plates is slightly depressed.

The median process is of the "type A" of Størmer (1933) and presumably belonged to a male. It is long and unusually stout, comprised of a long basal segment which is proximally hastate, and a pair of long blades which are closely appressed on the median line (perhaps sutured) to form a lanceolate stiletto. The over-all length of the median organ is 53 mm.; the width of the non-hastate base is 7.2 mm.; the blades measure 19 mm. The halberd is 8 mm. wide and of approximately the same length. The haft portion of the basal segment shows no evidence of transverse division and would seem to be historically a single element. A depressed median line runs the length of the haft, becoming more deeply impressed distally. This may reflect the ancestral paired nature of the process, although this depression could not now be called a suture. The distal lateral margins of the haft bear a narrow flange which appears to be set off from the main axial process by a suture. However, this appearance may be due to slight abrasion of a carina, rather than a true suture. Lateral arcuate ridges of a slightly nodose character originate just inside the flange a short distance in front of the termini of the opercular wings, and become evanescent at the point where the hastation commences. These lateral carinae appear to have interlocked with the mesial margins of the lateral lobes of the posterior opercular plates in life. Across the area of junction between haft and hastation, the process surface is elevated in an elongate node; the wings of the halberd are broadly depressed. The hastate portion and proximal shaft are unornamented; the distal shaft bears small imbricate scale-like ornament. The distal corners of the haft are produced as blunt wings; the distal margin is emarginate and mesially slotted.

The distal blades are articulated (movably in life?) to the distal margin of the basal segment. They meet on the saggital line in a sharply incised line which may be a suture. Together they create a sharp, lanceolate stiletto. Their tips are slightly divergent and rounded, in the manner of a steel pen, which suggests that they may not have been sutured in life, and they may even have functioned like a steel pen in conduit fashion. A flat-topped axial ridge extends from the tip to the base of each blade and increases in prominence toward the front. The outer halves of the blades are shallowly excavate and the lateral margins slightly keeled. No ornament is observed on the blades.

Occurrence.—The holotype comes from the Upper Silurian (Cayugan) dolomites of Jerusalem Hill, Herkimer County, New York. The horizon has been identified as the lower member of the Bertie limestone of western New York—the Fiddler's Green "limestone" of the more recent New York State stratigraphers. Eurypterids occur in the upper part of the Fiddler's Green unit. Facies relationships are considered in the foregoing introduction. This locality is famous through the works of James Hall (1859, etc.) and the eurypterid monograph of Clarke & Ruedemann (1912). No doubt

the specimen was picked up from float on Jerusalem Hill, like most of the famous material from this site, for actual exposures are rare on Jerusalem Hill. The locality is just northeast of the settlement of Jerusalem, Town of Litchfield, Herkimer County.

Type.—Holotype No. 5663, Jewett Collection, Geology Department, Cornell University, Ithaca, New York.

Remarks.—Dolichopterus jewetti is easily distinguished from any related eurypterid by the ponderous porportions of the genital appendage as a whole, and the very large size of the distal process blades. The closest American resemblance is to the western New York species *Dolichopterus macrocheirus* Hall, wherein, however, the process blades are shorter, more spine-like, and being clearly discrete were incapable of forming a stiletto.

Clarke & Ruedemann (1912, pl. 43) figure a nearly complete specimen which also was collected at Litchfield, New York. This specimen was identified as *Dolichopterus macrocheirus* Hall by said authors but properly should be referred to *D. jewetti*. The operculum is of type "B," presumably the female. The swimming leg is much slenderer and along with numerous minor differences in the proportions of the joints (particularly the sixth joint past the coxae) denote a distinct form from the Buffalo *D. macrocheirus*. The Herkimer species also has a greater development of spurs on the metasomal tergites than the latter. All other specimens figured by Clarke & Ruedemann are western forms, or from the Buffalo district, and properly belong to *D. macrocheirus* Hall.

DOLICHOPTERUS TESTUDINEUS Clarke & Ruedemann, 1912 and D. HERKIMERENSIS, n. sp.

Under the name *Dolichopterus? testudineus* Clarke & Ruedemann (1912, p. 275) described two specimens of unusual characteristics. Both are from Cranes Corners, Herkimer County, New York, but to the present writers each specimen represents a distinct species. The holotype (op. cit., pl. 57, fig. 2) is a rounded dorsal shield with large sickle-shaped eyes. The paratype retains part of the dorsal shield, first tergite and complete swimming leg. The holotype distinctly reveals genal angles which are obtuse and not forming a right angle as in the paratype. The holotype of *D?. testudineus* seems much more easily accommodated in the Stylonuridae than in the Dolichopteridae. The large sickle-shaped lateral eyes and the median ocelli midway between the eyes are distinctly stylonuroid rather than dolichopteroid. In the latter category the eyes are smaller, less sickle-shaped and the ocelli are located further back on the head. Were the dorsal shield holotype of Clarke & Ruedemann less rounded, it would conform quite satisfactorily to Størmer's genus (1951, p. 416) *Brachyopterus*, to which it may still very well pertain. The paratype definitely represents a *Dolichopterus* quite distinct from any associated form and is herein named *Dolichopterus herkimerensis*. The details of the unusual swimming leg, as well as the great length of the first tergite serve to distinguish this form from any known eurypterid. The latter characteristic is known only in the Carboniferous Mycteropteridae and quite unanticipated in Silurian Eurypterida.

DOLICHOPTERUS STØRMERI, n. sp.

Eurypterus laticeps Schmidt from the well-known *Eurypterus fischeri* Upper Silurian fauna of Rootsikula, Saaremaa (Oesel), has been treated by various authors as an *Eurypterus* and a *Dolichopterus*. *E. laticeps* was based on two well-preserved prosomas (Schmidt, 1883, p. 63–64, pl. 3a, fig. 16; pl. 6, fig. 15). These specimens indicated a species characterized by a very wide prosoma which was margined by pustules and bore scattered pustules on the glabellar area. On his pl. 7, fig. 9 Schmidt showed a swimming leg clearly pertaining to *Dolichopterus* but which he questioningly referred to *Erettopterus osiliensis* (Schmidt).

Schmidt's initial confusion was further complicated when Holm recognized an operculum (1898, pl. 4, fig. 3) and a metastoma (1898, pl. 10, fig. 10) from the same fauna as belonging to the genus *Dolichopterus*, but also he believed to Schmidt's species *laticeps*; hence the reassignment of the species to *Dolichopterus*. At the same time Holm (1898, pl. 10, fig. 11) figured another metastoma which he referred to

Dolichopterus sp. However, it develops that Schmidt's original types definitely pertain to *Eurypterus* and not to *Dolichopterus*. This fact was long unappreciated; hence, as a consequence of Holm's revision, Schmidt's species has appeared in subsequent publications attributed about equally to the two genera. Such was the state of uncertainty that we find Clarke & Ruedemann (1912, p. 172) unquestioningly referring *laticeps* to *Eurypterus* in order to prove the close affinity of *E. remipes* to *E. lacustris* and in a footnote (p. 261) "prove" *E. laticeps* to show strong resemblances to the *Stylonurus-Dolichopterus* group, and on the same page just as unquestioningly refer to the species as *Dolichopterus laticeps!* O'Connell (1916, p. 50 and 236, e.g.) uses both *Eurypterus* and *Dolichopterus* in referring to Schmidt's species.

Størmer (1934, p. 7) was the first correctly to note that Schmidt's types represent an *Eurypterus* and that Holm's specimens belong to wholly different species. He suggested the nomenclatorially impossible solution to the matter by retaining *laticeps* for both species. Thus he listed them as *Eurypterus laticeps* Schmidt and *Dolichopterus laticeps* Holm. In reality Holm proposed no new species, and his labels are clearly a misidentification.

The operculum described by Holm (1898, pl. 4, fig. 3) exhibits a long mesial appendage and most of the opercular flaps. This form clearly reveals the characteristic anterior paired plates described for *D. jewetti*. The metastoma (Holm, 1898, pl. 10, fig. 10) shows the same ornamentation as *Dolichopterus* and quite probably pertains to the same species as the operculum. It is now proposed that these be known as *Dolichopterus stormeri* Caster & Kjellesvig-Waering, n. sp.; the operculum will serve as the holotype. The species is appropriately named in honor of Leif Størmer who first correctly revealed the basis for the confusion. *D. stormeri* differs from *D. jewetti* in having a less ponderous development of the mesial appendage.

The swimming leg which Schmidt (1883, pl. 7, fig. 9) questioningly referred to *Erettopterus osiliensis* is undoubtedly a *Dolichopterus* leg and should be referable to *D. stormeri*. The metastoma which Holm (1898, pl. 10, fig. 11) designated as *Dolichopterus* sp. may be referred to another species of *Dolichopterus* as yet unnamed.

DISCUSSION

With respect to general eurypterid morphology, the operculum of *D. jewetti* affords several structures of considerable interest and possibly wide bearing. At this stage it may be unkind to recall that Clarke & Ruedemann in their great monograph (1912, p. 60–61) wrote:

> The operculum of the eurypterids consists of *a pair of plates* [italics ours] meeting in the median line and having a median lobe attached to them. . . . The scales form a continuous transverse line across the plates which has been erroneously considered as the suture resulting from the fusion of two sternites. In front of the median lobe two triangular—or sometimes pentagonal—areas are marked off [in some eurypterids].

These authors appear to have discounted completely Holm's (1898) observation of a clear-cut transverse suture on a Baltic operculum, the specimen here serving as the holotype of *Dolichopterus stormeri*, n. sp. Thus for Holm the eurypterid operculum was comprised of two pairs of opercular plates, and the modern consensus would probably be in accord with Holm's opinion. The argument has devolved mainly into the interpretation to be placed on the meaning of transverse lines, often ornament, such as fine scales, which transversely cross the seemingly single pair of plates in such forms as *Eurypterus remipes*, *E. lacustris*, and *E. fischeri* (among the best known eurypterids).

Like Holm, we are deeply impressed by the unquestioned transverse suture, and feel there is a very good possibility that this reflects an archaic condition of the eurypterid operculum, i.e., either an original suture between the ancestral sternites now modified into this genital organ, or the contacts between comprising exopodite appendages. At the same time, it seems very clear that the complete obliteration of the suture came very early in the Eurypterida, as witness the complete absence of all evidence in the Megalograptids (Caster and Kjellesvig-Waering, 1956, in press) of the late Ordovician.

An additional anachronistic trait of

Dolichopterus is the unique preservation of a proximal third pair of opercular plates. The holotype of *D. macrocheirus*, in the American Museum of Natural History clearly shows the proximal pair of plates, which Hall, and Clarke & Ruedemann failed to notice. Although Clarke & Ruedemann appear to have given no thought to the possibility of these opercular components, Størmer (1933, p. 44) has discounted the possibility. He pointed out that in many eurypterids the sole scale-like ornament on the operculum occurs at the anterior margin, and is often sharply delimited. He looked upon this delimitation as a "false suture." Still he speculated, in the same place, that if the delimitation did represent an obsolescent suture, it might reflect the contact between the first and second sets of exopodites to be incorporated into the operculum. *Dolichopterus* would seem to suggest that the ornamental demarcation does *not* necessarily reflect the position of an ancient suture, but that nevertheless a genuine suture did exist, irrespective of the ornament pattern. In *Dolichopterus*, it will be recalled, the suture is distad of the ornament border by nearly half the length of the anterior plates. It seems to us well worth considering the strong possibility that three paired elements have entered into the composition of the lateral operculum. However, with respect to these plates, as with respect to the transverse suture, the complete union to a simplified operculum seems to have been an early attainment, for the megalograptids show no evidence of the anterior plates. Of possible bearing on the homologies of the anterior opercular plates is the fact that in *Dolichopterus* the anterior opercular margin is sharply defined and rectilinear, whereas in most eurypterids this margin becomes evanescent and frayed, as Størmer (1933) pointed out. Perchance in some forms the anterior plates have disappeared in the zone of articulatory contact between the coxae and the operculum.

Another novel structure of considerable interest in *Dolichopterus* is the pair of lanceolate plates which are sutured to the medial border of the posterior opercular plates. These new plates are here called the *lateral lobes*. Although their position in life seems usually to have been concealed above the margins of the genital process, and hence not commonly observable, especially in the better-known eurypterids, in others they had a hypertrophic development. Caster & Kjellesvig-Waering describe (1955, p. 1040–1041) what appear to be homologous structures in a female ("type B") operculum from the Downtonian beds of the Welsh Borderlands. In his new genus and species the operculum consists of a pair of large plates which are confluent, without suture distad of the clavate and two-segmented median process. On either side of the process two free lateral lobes are seen. Kjellesvig-Waering recognized these as the antecedent homologues of the striking "spatulate plates" in the opercula of Meek & Worthen's Pennsylvanian *Adelophthalmus mazonensis* from Illinois. Kjellesvig-Waering (1948, p. 23, pl. 1, fig. 6) shows the spatulate plates to have been present in both males and females of the Mazon Creek form. Here, as in *Dolichopterus*, the "lobes" are sutured to the adjacent opercular plates, and in the Pennsylvanian females are also broadly sutured to the median appendage, only the tip of which appears to have been free. In both the Downtonian and the Pennsylvanian forms the large opercular plates seem to be composite structures in which the transverse suture has diasppeared. What may have happened to the anterior plates is more hazardous to speculate.

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 29–34, PL. 5, JANUARY 1956

A NEW UPPER CANADIAN FAUNA FROM A DEEP WELL IN TENNESSEE

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ABSTRACT—A deep well near Danceyville, Haywood County, Tennessee, has produced a unique brachiopod fauna. It consists of nine species representing nine genera, all of which occur elsewhere in the upper Canadian but which have hitherto not been found together. The genera are *Archaeorthis*, *Orthambonites*, *Orthidium*, *Hesperonomia*, *Tritoechia*, *Pomatotrema*, *Diparelasma*, *Leptella* and *Camerella*.

INTRODUCTION

IN 1945, Mr. Kendall E. Born, then Associate Geologist of the Division of Geology, Department of Conservation, State of Tennessee, submitted to the Smithsonian Institution a small collection of core fragments from a well in Haywood County, ¾ mile north of Danceyville, drilled by C. L. Maguire, Inc. According to Mr. Born, and based wholly on lithology, this well showed the "Cretaceous resting upon pre-Trenton beds, probably some part of the Black River-Stones River sequence." Examination of the fossils in their unprepared state certainly suggested a correlation along the lines indicated. In spite of this, the assemblage was not quite right for early Middle Ordovician fossils. The solution could be found only in close identification of the fossils which were almost all brachiopods.

These brachiopods were an unpromising lot because they were all small and all exfoliated so that neither true interiors nor exteriors were available. In order to get interior information from some of the exfoliated valves, the specimens were washed with acid. This treatment was designed to thin the shells sufficiently to reveal septal and cardinalia sutures. During this treatment, it was discovered that the matrix was strongly magnesian and that the brachiopod shells dissolved away and left fairly faithful imprints of the interior. This happy situation made it possible to get interiors of the most troublesome genera and to prove that the brachiopods belong to the late Canadian, probably Black Rock formation, rather than Black River as originally suspected. Inasmuch as this interval of the upper Canadian was hitherto unknown in Tennessee and the brachiopod assemblage is unique, I thought it desirable to make this record of the findings.

Identifications of the brachiopods are:

Archaeorthis cf. *A. costellata* Ulrich & Cooper
Orthambonites alabamensis (Ulrich & Cooper)
Orthidium aff. *O. gemmiculum* (Billings)
Hesperonomia cf. *H. subtransversa* Ulrich & Cooper
Tritoechia cf. *T. sinuata* Ulrich & Cooper
Pomatotrema cf. *P. oklahomense* Ulrich & Cooper
Diparelasma cf. *D. magnum* Ulrich & Cooper
Leptella nevadensis Ulrich & Cooper
Camerella arkansasensis (Ulrich & Cooper)

Three of these genera, *Orthambonites*, *Orthidium*, and *Camerella*, range from the upper Canadian into the overlying Middle Ordovician strata. *Tritoechia* and *Archaeorthis* extend from the upper Canadian down into the middle Canadian. All of the other genera are confined to the upper Canadian. Several of the genera have wide geographic ranges: *Archaeorthis*, *Orthambonites* and *Tritoechia* occur from Quebec to Alabama and into the Great Basin and the last is known also from Greenland; *Orthidium* is known from Newfoundland to the Great Basin; *Diparelasma* occurs in Newfoundland and is abundant in the Appalachians, the Midwest, and the southern part of the Great Basin but is uncommon in the Canadian Rockies; *Hesperonomia* occurs rarely in the Midwest but is common in the Great Basin; *Pomatotrema* is known from Greenland to the Arbuckles of Oklahoma but is exceptionally rare in western United

States and western Canada; *Leptella* is known from Quebec to the Great Basin; and *Camerella* is known from the high Canadian in Quebec, the Midwest and the Great Basin.

The top of the Paleozoic was reached in the well at 2125 feet. The core samples are labelled between 2126 feet and 2145 feet and thus represent only 20 feet of section. The rock is dark gray, fine-grained and contains scattered fossils. Besides brachiopods, only a few other specimens were seen. These include fragments of one or two asaphoid trilobites and a large planispiral snail so badly exfoliated as to be unidentifiable.

The brachiopod assemblage is unique. In spite of this, all of the genera are known to have late Canadian affinities and the nearest specific identifications possible place the assemblage at about the level of the *Kirkella* zone of the upper Pogonip, the Black Rock-Smithville of Arkansas, possibly Odenville of Alabama and possibly part of the Nunatami formation of Greenland and part of the St. George series of Newfoundland. The latter two however may be somewhat older than the fossils from the Maguire core.

SYSTEMATIC PALEONTOLOGY

ARCHAEORTHIS cf. A. COSTELLATA Ulrich & Cooper

Pl. 5, D, fig. 8–15

Shells small, the largest measuring about 4 mm. in length and slightly more in hinge width; pedicle valve moderately convex in lateral profile but almost carinate in anterior profile; brachial valve convex in the posterior but the anterior half to three-quarters gently concave. Sulcus of brachial valve broad but shallow. Surface costellate, costellae numbering from 40 to 60. The pedicle interior has a low callosity anterior to the muscle scars as is characteristic for the genus but this callosity widens anteriorly and is definitely triangulr in shape. The brachial valve has stout brachiophores.

Figured specimens: USNM 124424, 124425, 124426 a–c; measured specimens: USNM 124423 b, 124428 b.

Location in well.—At 2126, 2130, and 2132–2135 feet.

Discussion.—This is one of the commonest species in the cores. It is referred to *A costellata* because of its small size, numerous costellae and broad sulcus. One of the specimens from the core has attained the size of adult *A. costellata;* consequently, the measurements vary somewhat and the costellae count is not the same, although it is what might be expected in young individuals.

The pedicle interior of *A. costellata* is not known, which makes direct comparison of inside features impossible. The interior of the brachial valve of *A. costellata* has stout brachiophores like those of the specimens from the well.

ORTHAMBONITES ALABAMENSIS (Ulrich & Cooper)

Pl. 5, E, fig. 16

Orthis alabamensis ULRICH & COOPER, 1938, Geol. Soc. Am. Special Paper 13, p. 99, pl. 14A, fig. 1–4.

Two levels furnished specimens of this species. The largest and best specimen is 5 mm. long and 6.1 mm. wide. Seventeen costae may be counted on the specimen, but the small ones on the ears are not visible and probably consisted of two on each ear. The profile is strongly convex with the greatest convexity in the umbonal region.

Hypotype: USNM 124433.

Location in well.—2126 and 2135 feet.

Discussion.—These specimens are suggestive of either *Orthambonites panderiana* or *O. alabamensis*, but the ribbing and shell proportions indicate the southern species rather than the Lévis one.

ORTHIDIUM aff. O. GEMMICULUM (Billings)

Orthidium gemmiculum (Billings) ULRICH & COOPER, 1938, Geol. Soc. Am. Special Paper 13, p. 112, pl. 16G, fig. 27–35.

Measurements in mm.

		length	brachial length	width	hinge width	thickness
Pedicle valve	124423 b	3.5	?	3.5	?	?
	124425	3.1	?	3.0	3.2	?
Brachial valve	124426 a	?	3.5	4.1	4.4	?
	124426 b	?	3.7	4.1	4.4	?
	124428 b	3.9	3.3	?	3.8 plus	2.7

Recognition of this genus is of considerable interest because of its general rarity and its unique structure. The specimen, a brachial valve, referred here is not a good one and the specimen is too poor to figure. It is small, measuring 2.2 mm. in length and 3.0 mm. in width. Unfortunately it was filled with non-dolomitic matrix; consequently, it was impossible to produce a good interior mould. In spite of this, the cardinalia can be seen in sufficient detail to recognize them as belonging to *Orthidium*. The brachiophores of *Orthidium* are so welded to the sides of the shell and the cardinal process as to form what appears as a single transverse plate. Furthermore, the ornamentation of part of the specimen is visible and it is strongly imbricating as in *Orthidium*.

Described specimen: USNM 124432.

Location in well.—2130 feet.

Discussion.—*Orthidium* is a rare and poorly known genus. It occurs in the high Poponip (past-Canadian but pre-Middle Ordovician) of Nevada and in the equivalent Table Head series of Newfoundland. The original type specimens were taken from limestone blocks in the limestone no. 2 at Lévis, Quebec, but these latter beds have never been satisfactorily dated.

HESPERONOMIA cf. H. SUBTRANSVERSA
Ulrich & Cooper
Pl. 5, A, fig. 1,2

Hesperonomia subtransversa ULRICH & COOPER, 1938, Geol. Soc. Am. Special Paper 13, p. 122, pl. 20B, fig. 5–8.

This species is represented by three brachial and two pedicle valves, none of them well preserved. The pedicle valve is a young specimen having a length of 8.4 mm. and a width of 14 mm. along the hinge. The interior details are characteristic for the genus, short dental plates and shallow delthyrial cavity. The median region from beak to anterior margin is somewhat swollen. The best brachial valve is 11.6 mm. long and 15.7 mm. wide at the hinge. This specimen is widely sulcate and the sulcus is fairly deep. The cardinal extremities are deflected toward the pedicle valve fairly strongly. Costellae number 11 to 12 in 5 mm. at the front margin. A small brachial valve from which the shell was dissolved shows the characteristic cardinalia, but they are not well-preserved.

Figured specimens: USNM 124430a, 124431a.

Location in the well.—2134 and 2145 feet.

Discussion.—This species is more like the Nevada *Hesperonomia subtransversa* than like the Black Rock and Smithville *H. plana*. It differs from the latter in having a widely sulcate brachial valve which is fairly strongly concave and the costellae and dimensions are like those of the Nevada species. *Hesperonomia* is a common and widely distributed upper Canadian genus.

TRITOECHIA cf. T. SINUATA
Ulrich & Cooper
Pl. 5, C, fig. 5–7

Tritoechia sinuata ULRICH & COOPER, 1938, Geol. Soc. Am. Special Paper 13, p. 167, pl. 32B, fig. 8.

A single pedicle valve is the only specimen of *Tritoechia* to appear in this strip of core. The specimen is 10.3 mm. long and 11.0 mm. wide. The interarea is apsacline; the lateral profile moderately convex but with the anterior half somewhat flattened. Anterior profile moderately convex; surface costellate, costellae number about four to the millimeter at the front margin. Costellae of assorted sizes but shell too much exfoliated to determine a definite pattern.

Figured specimen: USNM 124429.

Location in well.—2126 feet.

Discussion.—The pedicle valve of the Maguire well specimen was compared with the holotype of *T. sinuata* which comes from the upper Pogonip (*Kirkella* zone) in Nevada. The proportions and profiles are similar but the costellae do not entirely agree. The Tennessee specimen seems to be somewhat more finely costellate, but it is more exfoliated than the Nevada shell. The costellae count on the Nevada shell is 4 to the millimeter but larger costellae are scattered among the mass of smaller ones. These larger ones are not apparent on the Tennessee specimen.

The Tennessee specimen is much closer to *T. sinuata* than to any other species yet described. *Tritoechia delicatula* is suggestive of the Tennessee specimen but is wider.

POMATOTREMA cf. P. OKLAHOMENSE
Ulrich & Cooper
Pl. 5, B, fig. 3, 4

P. oklahomense ULRICH & COOPER, 1938, Geol. Soc. Am. Special Paper 13, p. 173, pl. 35B, figs. 2–5, 7–12.

The single specimen of a pedicle valve of this species measures 7.5 mm. in length and 10.4 mm. wide. The interarea is apsacline, the beak broadly obtuse and the greatest width is at the hinge. The sides slope obliquely toward the middle. Lateral profile gently convex and with the maximum convexity near the middle; anterior profile broadly convex. Surface costellate, costellae consisting of strong ribs separating groups of finer costellae all covered by strong concentric fila.

Figured specimen: USNM 124434.

Location in the well.—2143 feet.

Discussion.—This specimen agrees well with pedicle valves of *P. oklahomense* in dimensions and profiles. The ornamentation of the Tennessee specimen is better preserved than that of any of the Oklahoma species which are silicified. Silicification often destroys the fine details of exterior ornament. What one gains in interior details

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EXPLANATION OF PLATE 5

A. *Hesperonomia* cf. *H. subtransversa* Ulrich & Cooper
1, Impression of the interior of the brachial valve, ×2, figured specimen USNM 124431a. *2*, Exterior of a somewhat exfoliated brachial valve, ×2, figured specimen USNM 124430a. Location in well: respectively 2143 and 2145 feet.

B. *Pomatotrema* cf. *P. oklahomense* Ulrich & Cooper
3, 4, Exterior of the pedicle valve, respectively ×2 and ×4, showing costellae and strong concentric fila, figured specimen USNM 124434. Location in well: 2143 feet.

C. *Tritoechia* cf. *T. sinuata* Ulrich & Cooper
5–7, Respectively pedicle, side and interarea views of the pedicle valve, ×2, figured specimen USNM 124429. Location in well: 2126 feet.

D. *Archaeorthis* cf. *A. costellata* Ulrich & Cooper
8, Exterior of an exfoliated pedicle valve, ×4, figured specimen USNM 124425. *9, 10*, Respectively impression of the muscle area of a pedicle valve prepared by dissolving shell and the plasticine replica prepared from it, ×4, figured specimen USNM 124426c. *11*, Brachial view of an exfoliated brachial valve, ×4, figured specimen USNM 124424. *12, 13*, Replica of the interior of a brachial valve showing thick brachiophores and the mould from which it was prepared, ×4, figured specimen USNM 124426a. *14, 15*, Interior mould of another brachial valve and the plasticine replica prepared from it, ×4, figured specimen USNM 124426b. Location in well: respectively 2126, 2132, 2135 and 2132 feet.

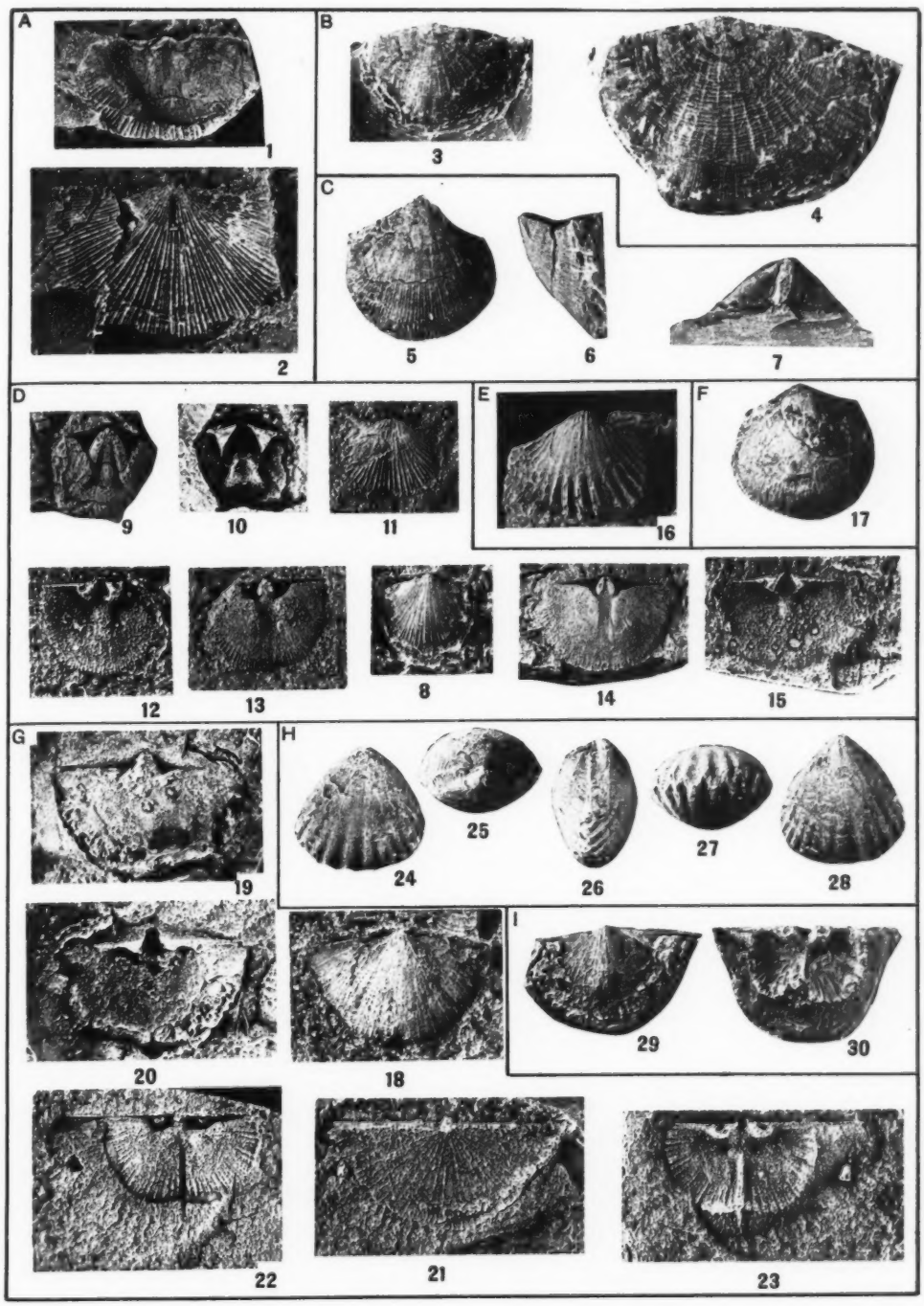
E. *Orthambonites alabamensis* Ulrich & Cooper
16, Exterior of the pedicle valve, ×3, hypotype USNM 124433. Location in well: 2135 feet.

F. *Diparelasma* cf. *D. magnum* Ulrich & Cooper
17, Exterior of a young pedicle valve, ×2, figured specimen USNM 124435. Location in well: 2141 feet.

G. *Leptella nevadensis* Ulrich & Cooper
18, Exterior of an exfoliated pedicle valve, showing large pseudopunctae, ×4, hypotype USNM 124437d. *19, 20*, Impression of the interior of the pedicle valve showing delthyrial cavity and stubby dental plates, and the replica of the pedicle interior prepared from it, ×3, hypotype USNM 124437a. Wavy concentric lamellae appear in the lower left side of figure 19. *21*, Exterior of the brachial valve showing costellae, ×4, plasticine replica prepared from mould of the exterior made by dissolving shell away, hypotype USNM 124437b. *22, 23*, Mould of the brachial interior prepared with acid, and plasticine replica of the brachial interior showing cardinalia and visceral disc, both ×4, counterpart of preceding hypotype. Location in well: 2135 feet.

H. *Camerella arkansasensis* (Ulrich & Cooper)
24–28, Respectively brachial, posterior, side, anterior and pedicle views of an exfoliated but otherwise perfect specimen, ×3, hypotype USNM 124436. Location in well: 2134 feet.

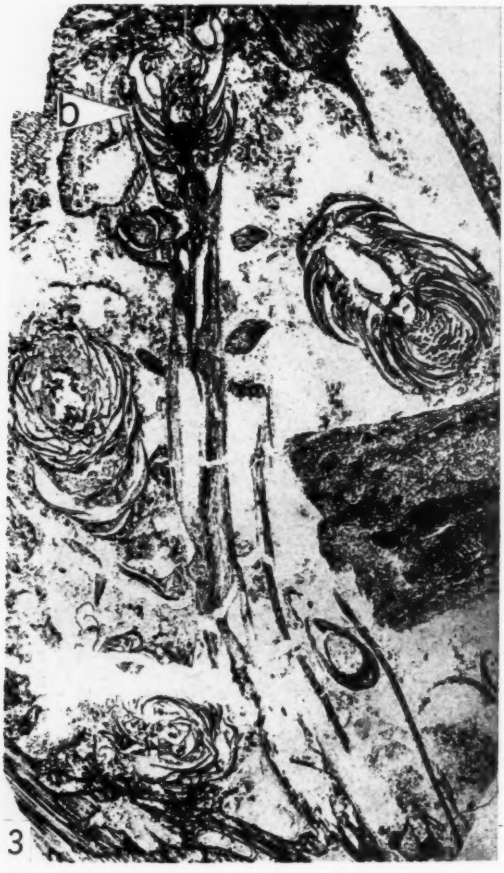
I. *Leptella nevadensis* Ulrich & Cooper
29, Exterior of the pedicle valve, ×2, showing costellate exfoliated posterior half and the lamellose anterior half, hypotype USNM 124443a. *30*, Interior of the brachial valve showing cardinalia and visceral disc, ×2, hypotype USNM 124443b. Horizon and locality: Pogonip group (*Kirkella* zone), 3½ miles southwest of Ninemile Canyon, Antelope Range, Roberts Mountains Quadrangle, Nevada.



Cooper, Upper Canadian brachiopods, Tennessee

a
1

2


b
3

4
c

through silification is often lost from those fine details of the exterior, which are characters that are among the best in defining species. The assignment to *P. oklahomense* must therefore be qualified.

DIPARELASMA cf. D. MAGNUM
Ulrich & Cooper
Pl. 5, F, fig. 17

Diparelasma magnum Ulrich & Cooper, 1938, Geol. Soc. Am. Special Paper 13, p. 150, pl. 28D, fig. 20–24.

A single pedicle valve is believed to be related to this species. It is 9.8 mm. long and 9.9 mm. wide, or nearly circular. The lateral profile is fairly strongly convex and the valve deep; anterior profile strongly convex; umbo swollen and beak strongly incurved. Thick dental plates are visible inside the shell when it is moistened.

Figured specimen: USNM 124435.

Location in well.—2141 feet.

Discussion.—This specimen is referred to *Diparelasma magnum* although the specimen is much smaller than the adults of that species, because of the strongly convex profiles, deep shell and circular outline. It differs from *D. circulare* from the Black Rock formation in the greater depth of the valve and its greater convexity.

LEPTELLA NEVADENSIS Ulrich & Cooper
Pl. 5, G, fig. 18–23; Pl. 5, I, fig. 29, 30

Leptella nevadensis Ulrich & Cooper, 1938, Geol. Soc. Am. Special Paper 13, p. 189, pl. 39G, fig. 16, 22.

Specimen of about usual size for the genus, wider than long; cardinal extremities acute, slightly alate; anterior margin broadly rounded; sides sloping toward the middle; surface costellate and lamellose; costellae of several sizes and grouped between larger ones, 2 or 3 of the larger costellae occupying one millimeter at the front margin. Concentric lamellae crowded along the anterior and lateral margins of the pedicle valve.

Pedicle valve moderately convex in lateral profile and with the maximum convexity at the middle; anterior profile broadly convex; median region swollen; cardinal extremities flattened. Interarea moderately long. Interior with short stout dental plates; delthyrial cavity narrow and shallow. Anterior of muscle region slightly thickened.

Brachial valve strongly concave with the greatest concavity in the median region; cardinal extremities gently concave. Notothyrium covered by a narrowly convex chilidium. Interior with short brachiophores surrounded by shell tissue to form cup-like sockets; cardinal process absent; visceral disc not strongly elevated; median septum low and narrow, not quite reaching to the notothyrial platform. Visceral disc striated.

Measurements in mm.

	length	brachial length	width	hinge width	thickness
Pedicle valve	6.5	?	8.4	9.2	?
Brachial valve	?	4.5	6.8	9.6	?

EXPLANATION OF PLATE 6

FIG. *1, 2*—*Cordaitanthus thompsoni*, n. sp. Longitudinal sections of a portion of the cone at two levels of sectioning. Note at *a* the terminal secondary fertile branch. ×3.5. (p. 39)

3—*Cordaitanthus shuleri* (Darrah), emend. Longitudinal section of the terminal portion of a male cone with microsporangia showing in the secondary fertile branch on the left. Details in Pl. 8, fig. 9. Note at *b* the terminal secondary fertile branch. ×2.5. (p. 38)

4—*Cordaitanthus compactus*, n. sp. Longitudinal section of the cone. Note the close spacing of the secondary fertile branches. At *c* is a subtending bract enlarged in Pl. 8, fig. 6. ×4. (p. 39)

Hypotypes: USNM 124437a,b,d, 124443a, b; unfigured hypotype: USNM 124437c.

Location in well.—2126, 2130, 2134, 2135 and 2145 feet.

Discussion.—This species is characterized by its transverse form, distinct costellae, low visceral disc and sharply defined median septum. It differs from *Leptella sordida* by its transverse form and subalate cardinal extremities and the more distinct costellae on the exterior. The specimens figured herein are mostly young specimens which are transverse and alate. These features appear in the younger growth stages of *L. nevadensis*, to which the Tennessee specimens are referred.

Leptella sordida (Billings) is known from limestone no. 2 of Lévis, the exact age of which is not now known. This limestone has fossils that link it to the upper Canadian and also possibly to the Mystic conglomerate. This species usually has a subquadrate outline and the costellation of the exterior is obscure in many specimens.

Leptella nevadensis Ulrich & Cooper is a rare fossil in the *Kirkella* zone of the upper part of the Pogonip group. Specimens of this species are larger than the Tennessee specimens and are not alate nor so strongly costellate because they are much older specimens. It shares with the Tennessee specimens the wrinkled, thin concentric lamellae on the exterior.

Leptella is a rare genus, but it is probable that it will ultimately be identified in the Mystic conglomerate of Quebec and in the Table Head series of Newfoundland. The interior characters of the Newfoundland Table Head species are little known, but they are an untapped source of new brachiopod information. In the core from Tennessee forming the subject of this paper, *Leptella* is the most abundant of the species found and occurs at five levels.

Camerella arkansasensis
(Ulrich & Cooper)
Pl. 5, H, fig. 24–28

Rhynchocamara arkansensis Ulrich & Cooper, 1938, Geol. Soc. Am. Special Paper 13, p. 250, pl. 56D, fig. 7, 12, 13.

A single, but nearly perfect specimen of this species was taken from the core. It measures 6.1 mm. in length, 5.9 mm. in width and 4.0 mm. in thickness. The specimen is subtriangular in outline, with subequally convex valves, the brachial valve having the greater depth. Both valves are moderately convex and have the greatest convexity on the umbones. The pedicle beak is low, protuding slightly posterior to the umbo of the brachial valve which is strongly swollen. The maximum width is in the anterior third which is marked by 13–14 short strong costae. The anterior commissure is rectimarginate.

Hypotype: USNM 124436.

Location in the well.—2134 feet.

Discussion.—*Camerella* is a rare genus in the upper Canadian, but it has been found in the Black Rock-Smithville formations of Arkansas and in the equivalent *Kirkella* zone of the high Pogonip group. This Tennessee specimen has the triangular outline and the ribbing characteristic of the Smithville species.

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NEW CORDAITEAN CONES FROM THE PENNSYLVANIAN OF IOWA[1]

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ABSTRACT—Coal balls containing petrified male cordaitean reproductive structures were studied using the peel technique. The resultant anatomical and morphological details necessitate a revision of *Cordaitanthus shuleri* to include only male cones. *Cordaitanthus thompsoni* and *C. compactus* are described as new species and are compared with all known petrified cones from North America, France and England. Possible reasons for the absence of petrified female cones in North American strata are considered but without arriving at a solution. The phylogeny of the conifer cone is reviewed briefly.

INTRODUCTION

INVESTIGATIONS in North America on petrified cordaitean reproductive structures have been confined to the work of Darrah (1940) and Delevoryas (1953). Darrah described both male and female cones under the name *Cordaianthus shuleri*.[3] The present study indicates that Darrah was in error and that as yet no petrifactions of female cones have been found in North American strata. Delevoryas (1953) named *C. concinnus* from coal balls collected in Kansas. Thus *Cordaitanthus shuleri* and *C. concinnus* constitute the only reported remains of petrified cordaitean cones on this continent. The present study adds to our knowledge of this group by describing two new species of cones and emending *C. shuleri* to conform with the established data.

Source of material.—All of the material studied was derived from coal balls collected by the late Mr. F. O. Thompson, Dr. H. P. Banks and the writer at the Atlas Mines, Mahaska County, and the Williamson Mines, Lucas County, in south-central Iowa. The coal balls from which the specimens came are part of the Paleobotanical Collections of the Department of Botany, Cornell University. In addition to his own material the writer had access to some 1700 slides made under the direction of Mr. W. C. Darrah and deposited at the Biological Laboratories, Harvard University. Renault's slides (1879) from the classic St. Étienne material were studied by the writer at the Muséum Nationale d'Histoire Naturelle in Paris. Florin's sections of St. Étienne material were also examined at the Riksmuseets Palaebotoniska Avdelning, Stockholm.

Technique.—The peel technique of Walton (1928, 1930) was used exclusively in making random and serial sections. Darrah's (1936) formula for peel solution was used. Concentrations of 1–5% HCl combined with etching intervals of 2 to 5 minutes were used to prepare the coal balls for peeling. The best peels were obtained from calcified coal balls containing little or no iron sulphide on which etching with 2% HCl did not exceed ½ to 2 minutes. Satisfactory peels were obtained from the more heavily iron sulphide-impregnated material, but prolonged grinding of the coal ball surface between peeling operations was necessary.

Selected peels were made into permanent mounts using a procedure initiated by rinsing each peel in 1% HCl for 30 seconds to remove any adhering particles of calcium carbonate. The peel was then washed in water and thoroughly dried. Following this the peel was immersed for 3 to 5 minutes in Eycleshymer's solution, a 1:1 mixture of phenol and cedarwood oil, as a means of improving the optical properties of the peel. The final step was a rinse in xylol followed by immediate mounting in H.S.R., a synthetic resin, dissolved in xylol.

[1] This paper represents a portion of a doctoral thesis completed in the Department of Botany, Cornell University, Ithaca, New York.

[2] Published by permission of the Acting Deputy Minister, Dept. of Mines and Technical Surveys, Ottawa, Canada.

[3] The reason for the use of the generic designation *Cordaitanthus* instead of *Cordaianthus* is given in a paper by the author in press with the Bulletin of the Torrey Botanical Club.

Stratigraphy.—Petrified cordaitean cones are restricted in their stratigraphic range to the Pennsylvanian (Upper Carboniferous). The early major contributions of Grand' Eury (1877), Renault (1879) and Bertrand (1911) are based exclusively upon silicified petrifactions from Stephanian strata near St. Étienne, France. Scott (1919) described a petrified cordaitean fructification obtained at Shore, Littleborough, in the British Isles. The Lower Coal Measures, from which Scott's specimens came, are lower Upper Carboniferous (Lower Pennsylvanian). Darrah's (1940) and Delevoryas's (1953) species came from coal balls found in coal seams which form a part of the vast Pennsylvanian cyclothemic deposits in the central United States. Precise stratigraphic correlation information is lacking but the approximate age of the strata in which cordaitean fructifications have been found is considered to be Des Moinesian (Middle Pennsylvanian).

MORPHOLOGY AND ANATOMY OF THE CONES

Terminology.—The terminology used in this paper reflects the concepts of Florin (1938–45, 1950, 1951) and Wilde (1944). A male cordaitean fructification is considered to be made up of an elongate axis bearing numerous small branches, each subtended by a bract. The entire structure is called a *cone*; the elongate axis is the *primary fertile branch*; the small branches are *secondary fertile shoots*, each bearing numerous sterile and some fertile appendages (see Text-fig. 1).

Gross morphology.—The largest of the petrified cordaitean cones examined measured 5.0 cm. in length by 2.0 cm. in width. This is small compared with the sizes reported for the numerous compressions of *Cordaitanthus*. The maximum size of cones preserved as compressions is up to 30 cm. in length and to 3.0 cm. in width. Since petrified cordaitean cones from coal balls are typically fragmentary, they should be regarded as portions of much larger reproductive structures broken up prior to petrification.

The primary fertile branch of the cordaitean cones is a stout axis with bud-like, secondary fertile shoots attached by very short stalks along its length (Pl. 6). Each is subtended by a small and inconspicuous bract (Pl. 6, fig. 4 at c; Pl. 8, fig. 6). An angle of 30°–40° is formed between the axis of the fertile shoots and the primary fertile branch. Drooping or pendulous secondary fertile shoots are never found. In instances where this seems to be the case, it is found that the fertile shoot has broken off of the primary fertile branch and bears no normal positional relationship to it. Terminal shoots have been found in three cones studied by the writer (Pl. 6, fig. 1 at a, fig. 3 at b). Thirteen secondary fertile shoots on a primary fertile branch is the largest number found attached in the course of this investigation. The spacing of the secondary fertile shoots along the primary fertile branch axis ranges from diffuse to closely placed. Where closely placed, the secondary fertile shoots come in contact with one another (Pl. 6, fig. 4).

An individual secondary fertile branch bears 40–95 appendages, a few of which are fertile. All of the appendages, sterile and fertile, are borne in the same compact spiral, causing the individual secondary fertile shoots to resemble grossly small bud-like structures. Fertile appendages in the Iowa specimens tend to be concentrated near the apex of the secondary fertile shoots (Pl. 8, fig. 9 at m). The shape of a secondary fertile shoot in median longitudinal section varies from rectangular in specimens from the Williamson Mine to globose in other specimens. Fertile shoots in median longtitudinal section measure 6.0–7.5 mm. in length by 5.0–6.5 mm. in width.

The secondary fertile shoots bear two types of sterile appendages, sheathing and acicular. The sheathing appendages are found on the lower third of the secondary fertile shoot. They are thick and broad, tapering to a point from a broad insertion on the axis of the secondary fertile shoot. The sheathing appendages of cones from the Williamson mine are exceptional because they are attached at right angles to the secondary fertile shoot axis. A short distance out from the axis they bend abruptly toward the tip of the fertile shoot. More typically the sheathing appendages curve gently toward the apex of the secondary fertile shoot from their line of insertion. They measure 3.0–4.0 mm. from base to apex. Each sheathing appendage is deeply concave on the adaxial side. In cross section they are crescent-

shaped and imbricate (Pl. 7, fig. 1, 5). Their longest dimension in cross section is 2.0–2.6 mm. from edge to edge. Nearer their apex, the crescent becomes progressively thinner and the distance between its extremities diminishes. These appendages terminate in a blunt apex. The sheathing appendages are comparable to tightly clasping and imbricated bud scales.

The acicular sterile appendages are slender and elongate. They are restricted to the upper two-thirds of a secondary fertile branch and attain lengths up to 8.0 mm. In cross section these acicular appendages are tetragonal and their largest dimensions average 540 μ in width by 250 μ in thickness (Pl. 7, fig. 6; Pl. 8, fig. 9).

Fertile appendages are interspersed among the sterile appendages but in the same spiral, and they tend to be concentrated near the apex of the secondary fertile shoot. Each fertile appendage consists of a stalk and several terminal sporangia. The fragmentary information available on the stalks indicates they are slender and terete, attaining lengths of a few millimeters. The diameters of the microsporangia are 250–480 μ and the lengths are 1500–1700 μ. As many as six microsporangia are found grouped together in clusters indicative of a normal association. Most of the specimens of microsporangia examined by the writer are filled with microspores. Empty sporangia are uncommon.

Anatomy of the cone.—The shape of the primary fertile branch in cross section varies between specimens as well as along the length of a single specimen. This shape ranges from nearly square to rectangular to roughly circular, with minor irregularities superposed on the basic form. The passing off of vascular traces to the secondary fertile branches further modifies the shape of the primary branch. The taxonomic value of the shape of the primary branch, therefore, is probably of minor importance (Pl. 7, fig. 1 at e, fig. 2 at f, fig. 8–10; Pl. 8, fig. 1, 2).

The epidermis of the primary fertile branch is composed of a single layer of cells. In surface view they are arranged in a brick-like pattern and average 54×21 μ with the larger measurement parallel to the axis of the branch. No stomatal apparatus is identifiable. A layer of cutin that attained a thickness of 100 μ covers the outer tangential walls of the epidermal cells. In many places this cuticle is broken free of the cone axis, and its rich brown color is particularly striking (Pl. 8, fig. 3 at j, fig. 8 at l).

The cortex is characterized by two distinctive zones of cells, an outer and inner (Pl. 7, fig. 8; Pl. 8, fig. 3). Four to six cell layers make up the outer cortical zone. These layers form a band around the entire cone axis and border irregularly upon the inner cortical zone (Pl. 7, fig. 8, 9; Pl. 8, fig. 3, 8). Characteristically the cells of the outer cortical zone are elongate, have moderately thickened walls, and have transverse end walls (Pl. 8, fig. 8 at k). In cross section, the secondary walls are usually shrunken away from the primary wall and appear as a ring or band within the cell. The longest cells measure up to 500 μ and are found in the peripheral layers of this zone. The average length is 100–200 μ. The shortest cells border directly on the inner cortical zone and are frequently thin-walled. Cross sectional diameters average 50 μ. The lumen of some scattered cells in the outer cortical zone is often plugged with a dense, dark brown or black substance.

The outstanding characteristic of the inner cortical zone of the primary fertile branch seen in longisection is vertical rows of thin-walled, isodiametric parenchyma alternating with mucilage canals. The canals form an anastomosing system in the cortex with three to five rows of parenchyma cells separating the canals at any one level. The parenchyma cells are 30–140 μ in diameter, averaging 75 μ. Numerous scattered cells in this parenchyma tissue are also filled with the dense, opaque material so common to cells of cordaitean fructifications. There appears to be no morphological similarity between these canals and the resin ducts of modern conifers.

Epidermal cells of the sterile appendages of the secondary fertile shoots are similar to those of the primary fertile branch. The cuticle attains thicknesses of 10–25 μ on the sheathing sterile appendages. The thin cuticle on the acicular, sterile appendages is difficult to detect.

Internally the sheathing sterile appendages of the secondary fertile shoot are differentiated into an adaxial and an abaxial

zone. Histologically the cells of the two zones resemble those of the two cortical layers of the primary fertile branch axis. Five to seven layers of elongate cells with transverse end walls comprise the abaxial portion of the sheathing appendage. Progressively, toward the apex of the sheathing sterile appendage, the layers of elongate cells are reduced in number until at the tip there are only two or three. The walls of these cells are moderately thickened, with the secondary portion of the wall in nearly all instances shrunken and appearing as a ring inside the cell. In cross section, these cells average 50 microns in diameter. In length, they range from 100–200 μ. Cells of this type possibly functioned as a protective layer, perhaps rendering the secondary fertile branch appendages nearly impervious to water loss or damage. The sheathing sterile appendages were probably woody or coriaceous.

Cells of the adaxial region of the sheathing sterile appendage are parenchymatous, and many of them are filled with opaque tanniferous or mucilaginous material. The parenchyma extends from the base to the tip of the appendage, but it is gradually reduced until at the tip there are only one to three layers. The parenchyma cells of this zone are 40–65 μ in diameter by 60–75 μ long.

The central vascular strand is surrounded by a zone of thin-walled parenchyma with abundant lacunae. The lacunae are always separated from the vascular strand by several rows of parenchyma.

The non-vascular components of the acicular sterile appendages are exclusively parenchymatous cells 30–45 μ in diameter. They are vertically elongate, attaining lengths of 250 μ, but the majority are between 100 and 200 μ long. The walls are sometimes slightly thickened. A band of cells, all of which are plugged with the dense mucilaginous or tanniferous residue surrounds the single, central vascular strand.

The bracts which subtend secondary fertile shoots are small, measuring 1.8–2.0 mm. from tip to tip. Their cellular makeup is identical with that of the sheathing sterile appendages except for a much smaller number of tannin or mucilage containing cells. They are supplied with a small, solid xylem strand coming off the primary fertile branch strand at nearly the same time as the xylem strand to the secondary fertile branch.

The xylem of the secondary fertile branch supply is composed of annular, spiral and scalariform elements, with the last greatly outnumbering the other types combined (Pl. 8, fig. 7). Where it has been possible to ascertain the development of the primary xylem, the mesarch condition prevails. The strand in transverse section shows the xylem elements in a characteristically radial arrangement.

The vascular supply to the secondary fertile shoots arises from the ends of the flattened, two-parted xylem strand of the primary fertile branch (Pl. 7, fig. 4, 8 at h, 9 at i). It is initially protostelic for a very short distance. Farther out it is siphonostelic. The siphonostelic condition becomes increasingly pronounced and the pith increases in diameter in regions farther out in the branch (Pl. 7, fig. 1 at d, fig. 4, 5). Finally, in the distal portion of the secondary fertile shoot, the vascular supply is a dictyostele, with a pith 600 μ in diameter in the center of the stele. The vascular bundles here are six to nine cells in tangential direction and five to eight cells in a radial direction, and the diameter of the stele is 1000 μ. The pith is parenchymatous and the tannin and mucilage containing cells are in an approximate 1:1 ratio to those having no discernible contents (Pl. 7, fig. 6, 8).

The composite, three-dimensional structure of the xylem of the secondary fertile shoot is best visualized as urn-shaped with a tendency in terminal secondary shoots for the top of the urn-shaped mass to be closed over. The surface of this xylem mass is punctured by gaps left by the departure of vascular strands to the sterile and fertile appendages (Pl. 7, fig. 3, 5 at g).

SYSTEMATIC EMENDATIONS AND DESCRIPTIONS

CORDAITANTHUS SHULERI (Darrah) Fry emend.

Pl. 6, fig. 3; Pl. 7, fig. 1, 2, 4, 8–10; Pl. 8, fig. 7, 9

Cordaianthus shuleri Darrah, 1940, p. 2–3, figs. 1, 7–9, 11, 14–17.

Emended diagnosis.—Male cones with numerous secondary fertile shoots borne in two rows on a flattened primary fertile axis. Secondary fertile shoots globose measuring

10.0 mm. long×5.5 mm. broad. Appendages of secondary fertile shoot up to 95, spirally borne. Sterile and fertile appendages, in same spiral, latter tending to be concentrated near apex of secondary fertile shoot. Sterile appendages of two types: sheathing and acicular. Sheathing sterile appendages 3.0 mm. broad×3.5 mm. long on lower third of secondary fertile axis. Sheathing appendages made up of two simple tissues: adaxially an isodiametric parenchyma containing numerous lacunae; abaxially an elongate, moderately thick-walled sclerenchyma. Acicular sterile appendages on upper two-thirds of secondary fertile shoot measuring 2.0 mm. broad×7.0 mm. long. Acicular appendages lacking sclerenchyma. Primary xylem of annular, spiral and scalariform elements. Primary fertile branch irregular to rectangular in transverse section, its xylem consisting of two narrow, flattened strands. Xylem supply to secondary fertile shoots arising from alternate ends of flattened strands of primary fertile branch as terete strands, the elements of which are radially arranged. The terete protostelic strand becomes successively siphonostelic and dictyostelic in the central and distal parts of the secondary fertile shoot. Pith with numerous mucilage, tannin or resin containing cells. Microsporangia up to six in number per stalk, apparently borne on slender, delicate sporophylls. Microsporophylls concentrated at apex of secondary fertile shoot with a few scattered in lower portions of the shoot. Diameter of sporangia 240–280 μ×1500–1700 μ long.

Microspores of the *Florinites* type (Pl. 8, fig. 14, 15).

Localities.—Iowa; Shuler Mine, Dallas County, Atlas Mines, Mahaska County.

Horizon.—Desmoinesian stage, Middle Pennsylvanian.

Hypotypes.—Figures 1, 7, 8, 9, 11, 14, 15, 16, 17.

Slides from the syntype.—A-249.1–5: A-466.4a–18; A-654.1–8; A-654.1–18. Deposited in the Paleobotanical Collections, Botany Department, Cornell University.

CORDAITANTHUS THOMPSONI n. sp.
Pl. 6, fig. 1, 2; Pl. 7, fig. 3, 5

Diagnosis.—Male cordaitean cones with preserved portion 3.2 cm. long. Secondary fertile shoots 6.8 mm. long×4.5 mm. broad borne in two rows along the primary fertile branch axis. Individual shoots widely spaced never coming in contact with one another. Appendages not exceeding 40. Sterile appendages of two types: sheathing and acicular. Sheathing appendages 3.0 mm.×3.6 mm. Acicular appendages to 4.0 mm. long. Xylem strand of primary fertile axis in two flattened parts and made up of radially arranged elements. Xylem strand of secondary fertile shoots siphonestelic to dictyostelic. Pith zone typically hollow or fragmentary. Numerous microsporangia on microsporophylls clustered at apices of secondary fertile shoots. Wall of microsporangia one to two cell layers thick, cells of which average 28.0×45.0 μ. Diameter of microsporangia 150–210 μ. Sporangia clustered at apex of secondary fertile shoot.

Locality.—Iowa, Atlas Mines, Mahaska County.

Horizon.—Desmoinesian stage, Middle Pennsylvanian.

Slides from the holotype.—A-634.1–4; A-634.1–10; A-634.1–58. Deposited in the Paleobotanical Collections, Botany Department, Cornell University.

Species name.—The species is named for the late Mr. F. O. Thompson who did much for paleontology in Iowa.

CORDAITANTHUS COMPACTUS n. sp.
Pl. 6, fig. 4; Pl. 7, fig. 6; Pl. 8, fig. 3, 6, 8

Diagnosis.—Cone of cordaitean plant 3.8 cm. long in preserved portion. Secondary fertile shoots arranged in two rows on primary fertile branch. Secondary fertile shoots very closely spaced and touching, measuring 10.0 mm. long×5.3 mm. wide having a rectangular shape in longitudinal section. Only 30–50 sterile appendages on secondary fertile shoots. Appendages of two types: sheathing and acicular. Sheathing sterile appendages 3.5 mm. wide×4.0 mm. long attached to axis of secondary fertile shoot by broad base, extending out perpendicularly from the axis before bending abruptly tipwards. Cells of sheathing appendages of two types: adaxially, parenchyma and abaxially, sclerenchyma with transverse end walls. Adaxial parenchyma zone containing few lacunae. Acicular sterile appendages to 8.0 mm. long, folding over and inward at the apex of the secondary fertile shoot. Primary fertile branch characterized by an anastomosing

canal system surrounded by parenchyma. Sex not ascertained.

Locality.—Iowa; Williamson Mines, Lucas County.

Horizon.—Desmoinesian stage, Middle Pennsylvanian.

Slides from the Holotype.—W-5-2.1-1; W-5-2.1-3; W-5-2.1-11. Deposited in the Paleobotanical Collections, Botany Department, Cornell University.

Comparison with previously described species.—*Cordaitanthus subglomeratus* Renault is characterized by globular secondary fertile shoots 2–3 mm. in length. They consist of a small number of spirally arranged sterile appendages and, at the apex, two clusters of sporangia each borne on a short stalk. The sterile appendages are thick and obovate. They curve inward, overlap, and the more distal ones completely cover the apex of the shoot. Fragments associated with the shoots indicate that additional clusters of microsporangia may have been present before fossilization.

Renault states that transverse sections of *C. subglomeratus* may show five secondary fertile shoots all attached to the cone axis. Individual shoots in such a section are cut at different levels. This seems to indicate a spiral arrangement of secondary shoots on the cone axis. However, the writer has explained how the apparent four rows of shoots in *C. shuleri* can better be interpreted as the actual two rows. The same suspicion holds here. Neither the specimens of *C. subglomeratus* nor the apparently four-rowed specimen of *C. shuleri* was fertile. In this connection Florin (1950) stated that the instances in which more than two shoots appear in one transverse section have never been proved to be cones, i.e., none were fertile. All cones examined by him have shown just two rows of fertile shoots. Considerable doubt attaches therefore to the statements by Renault that *C. subglomeratus* has spirally arranged secondary fertile shoots.

Cordaitanthus saportanus is based upon the description of isolated secondary fertile branches 7 mm. long. The sterile appendages do not cover the apex of the shoot as in *C. subglomeratus*. The short fertile appendages (microsporophylls) are borne near the apex of the shoot axis and bear four to five terminal sporangia. A single vascular strand enters the stalk and divides. Smaller strands then run into the bases of the individual microsporangia. Dehiscence of the sporangia occurred on the inner face longitudinally (Renault, 1879, pl. 17, fig. 3; Florin, 1951, fig. 12).

Cordaitanthus penjoni has secondary fertile shoots about 1 cm. in length with micro-

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EXPLANATION OF PLATE 7

FIG. *1, 2*—*Cordaitanthus shuleri* (Darrah), emend. Sections showing at *e* and *f* the configuration of the primary fertile branch in cross section. At *d* is the siphonostele of the secondary fertile branch. The flat, two-parted stele of the secondary fertile branch at *e* is enlarged in Pl. 7, fig. 4. ×12.

3—*Cordaitanthus thompsoni*, n. sp. Detail of the trace to a sterile appendage of the secondary fertile branch. Enlarged from a section similar to Pl. 7, fig. 5 at *g*. ×110.

4—*Cordaitanthus shuleri* (Darrah), emend. The xylem strand of Pl. 7, fig. 1 to the left of *e* enlarged. Note the radial alignment of the scalariform elements comprising the flattened, two-parted xylary tissue of the primary fertile branch axis. ×100.

5—*Cordaitanthus thompsoni*, n. sp. Cross section of a secondary fertile branch showing siphonostele at *g* and overlapping sterile appendages. ×20.

6—*Cordaitanthus compactus*, n. sp. Tangential longitudinal section of a secondary branch. ×22.

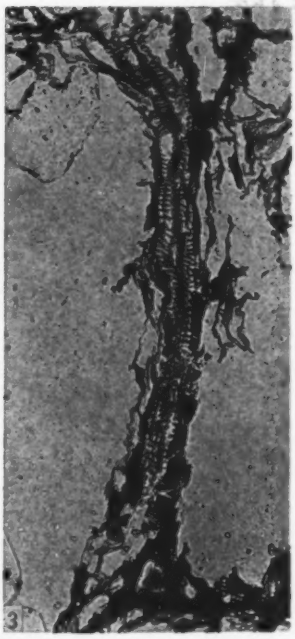
7—A longitudinal section through a cordaitean plant part, the morphological nature of which is controversial. ×1.5.

8—*Cordaitanthus shuleri* (Darrah), emend. Cross section of a primary fertile branch axis. Note the two-parted, flattened xylem strand just to the right of *h* and the cortical zonation. ×15.

9, 10—*Cordaitanthus shuleri* (Darrah), emend. Transverse sections of the primary fertile branch axis showing its configuration. Note to the right of *i* the departure of the xylary strand to the secondary fertile branch. The flat vascular strands of the primary fertile branch are also apparent. ×14.

d
e

f
2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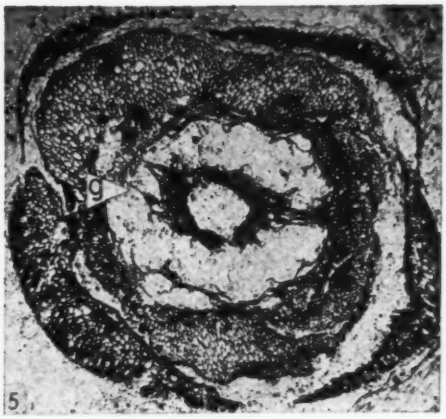
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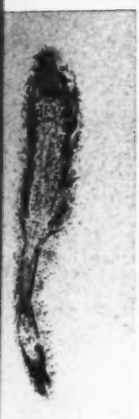

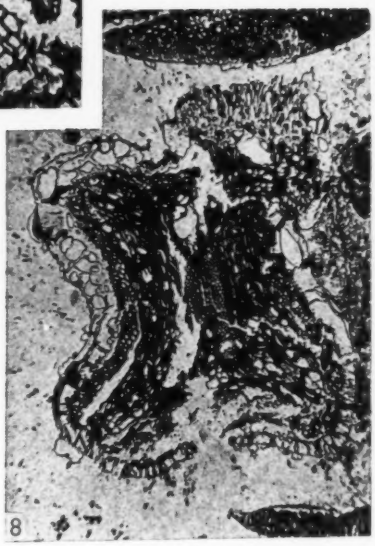
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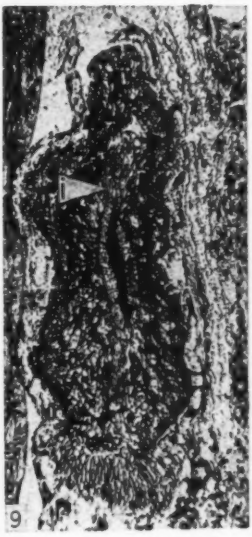
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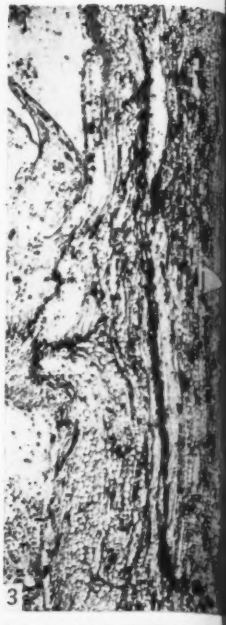
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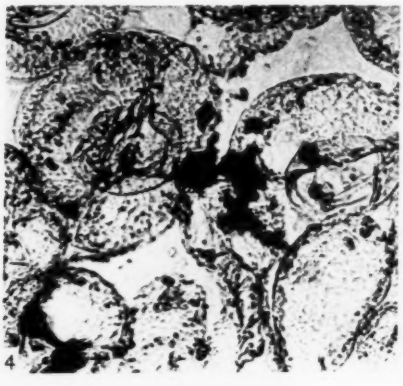
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sporophylls inserted throughout its length but most numerous at the apex. They are in the same spiral as the sterile appendages. The appendages number approximately one hundred, are linear-lanceolate in shape, and have a single strand of vascular tissue. Those that are fertile bear six microsporangia (Florin, 1951, fig. 11c). They are flattened and notched at the distal end where the microsporangia are attached. From the region of the notch, strands of vascular tissue run to the base of each upright microsporangium. The microsporangia are exserted and are so numerous that they must have given the entire fertile shoot a covering of sporangia.

Cordaitanthus concinnus is based on specimens described by Delevoryas (1953) originating from Kansas coal balls. It is a male fructification consisting of a slender, elongate, fluted axis 1–2 mm. in diameter. Along the length are borne two rows of secondary fertile branches 6.0 mm. long×3.0 mm. in diameter. Each of these secondary fertile branches is borne in the axil of a subtending bract. The bract extends in this species for some distance beyond the length of the secondary fertile branch. Along a short cylindrical axis are borne 25–40 spirally arranged sterile appendages. The basal sterile appendages are shorter than the upper ones and are more rounded at their apex. Five to ten appendages of the secondary fertile branch are fertile and located at the apical end of the fertile branch. They apparently protrude from the cover of the enclosing sterile appendages. Each fertile appendage typically bears six terminal sporangia. This is similar to *Cordaitanthus shuleri* and *C. saportanus* but differs from *C. penjoni*. The sporangia are fused at their base and are borne on tapered sporophylls. Sporangia are typically empty. They measure 1.0 mm. long×0.2 mm. in diameter.

DISCUSSION

Absence of female cones in North American strata.—Darrah (1940) described a new species of cordaitean cone, *Cordaitanthus shuleri*, from the Desmoinesian series in Iowa and Kansas. In this paper Darrah remarked that "*Cordaianthus shuleri* is the only species based on fructifications of *Cordaites* (or *Mesoxylon*) from which both staminate and ovulate strobili are known." Darrah was apparently in error. The writer examined some 1700 slides made by Darrah and found no recognizable ovulate cones. Instead the writer has concluded that Darrah's "ovulate" buds were tangential sections through closely grouped sterile sheathing appendages. In *Cordaitanthus* the number of these mucilage-tannin-resin-containing cells is very large. These cells appear completely filled with a dense, opaque material. Cells of this nature are a prominent feature of parenchymatous zones in *Cordaitanthus*, and in some regions, such as the

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EXPLANATION OF PLATE 8

FIG. *1, 2*—*Cordaitanthus compactus*, n. sp. Sections of primary fertile branch with attached secondary fertile branch. Note the cross sectional shape of the primary fertile branch. ×20.

3, 8—*Cordaitanthus compactus*, n. sp. *3*, Median longitudinal section of a primary fertile branch. At *j* are the large cells of the epidermis covered by a thick cuticle. ×15. *8*, Enlargement of a section of fig. 3 illustrating to the right of *k* the outer and to the left the inner cortical zones and at *l* the epidermis and cuticle. ×24.

4, 5—*Florinites* cf. *F. antiquus*. Microspores of *Cordaitanthus* spp. Note the reticulation found on the inner surface of the exine. The spore body is enclosed within the expanded exine or air bladder. ×570.

6—*Cordaitanthus compactus*, n. sp. Longitudinal section of a subtending bract in the axil of which is borne a secondary branch. ×30.

7—*Cordaitanthus shuleri* (Darrah), emend. Longitudinal section of a a portion of the xylem of a primary fertile branch showing on the left the separation of the xylem supply to the secondary fertile branch. ×115.

9—*Cordaitanthus shuleri* (Darrah), emend. Tangential longitudinal section of a secondary fertile branch. At *m* are numerous microsporangia containing microspores. Note in the lower portion of the figure the sections through the sterile appendages illustrating their spiral arrangement. ×10.

pith, they comprise about half the cells. A tangential section through a sheathing sterile appendage, cut through the region of the opaque cells, simulates an ovule near the apex of a secondary fertile shoot. The writer reached this conclusion during the summer of 1950 upon completion of his examination of the Darrah slides. In 1950, Florin, in a paper on female reproductive organs of the Cordaitineae remarked "I am inclined to believe that the dark patches in the centers of the buds only represent sterile leaves which have been cut parallel to their surfaces." In conversation in Stockholm during the summer of 1951, Florin and the writer came to full agreement that these dark patches are aggregations of cells filled with some opaque substance. There was also general agreement that North American strata have yet to yield petrified female cordaitean cones.

This raises the perplexing question of why petrified ovulate cones have not been identified in North American deposits. The present investigation has dealt with male cones simply because the writer could find no female reproductive organs. Literally thousands of coal balls have been cut and examined by numerous workers in studies of petrifactions from the Carboniferous. Leaves, stems, roots and seeds are present, but only the male cone is identifiable. Andrews, Schopf and Stewart (letters to Dr. H. P. Banks, 1950) state categorically that they have not seen ovulate cones. These reports and the absence in the literature of any verified reports of petrified female cones substantiate the statement that as yet no one has found a petrified female cordaitean cone in North America.

Their absence can be attributed to either our inability to recognize them as such because they are morphologically dissimilar to the male cone or female cones from Europe or to their failure to be incorporated in coal balls. The argument of morphological dissimilarity is tenuous in that a large number of female cones are known as compressions and these do not differ strikingly from the male cone compressions. Neither do petrifactions of male cones, although smaller in over-all size, differ from compression forms. Since the described petrifactions of female cones from Europe consist only of individual secondary fertile shoots broken away from the primary fertile branch, a remote possibility exists that compressions of female cones are an abnormal form and were, therefore, shed more frequently and as more complete entities. The absence of petrified female cordaitean cones suggests the possibility of their more ready decay and disintegration in the forest litter as compared with male cones.

Schopf (letter to H. P. Banks, 1950) suggests an explanation for the absence of female cones based on the maturation cycle of the plant. He postulates male cones shed as units after sporangial dehiscence. Female cones, under this concept were retained on the tree and dropped piece by piece. Even if this concept could be supported, it seems probable that conditions of storm and natural breakage in the forest would have caused female cones occasionally to fall onto the forest floor and by chance be preserved among the abundant coal ball remains.

A further suggestion of Schopf is the possibility that the female cones proliferated after seed shedding, thus continuing growth as vegetative shoots. There is some evidence to support this concept. In coal balls examined by the writer there are a number of elongate axes on which are borne upwards of one hundred appendages arranged in a close spiral (Pl. 7, fig. 7). The appendages are very similar to the sterile appendages borne on the male secondary fertile shoots. These axes may be parts of proliferated female cones or they may, as usually interpreted, be terminal vegetative shoots.

The concept of female cones shedding piecemeal gains support from an examination of compression material in which secondary fertile shoots bear seeds exserted on delicate, elongate stalks. Seed stalks of this nature may have abscissed readily, leaving apparently sterile cones. The presence of numerous sterile secondary fertile shoots and of numerous isolated cordaites seeds in coal balls remains lends support to the abscission concept.

In the opinion of this investigator the problem of the missing female cordaitean cone will be solved only by continued cutting of cordaite-containing petrifactions. The writer does not support the idea that

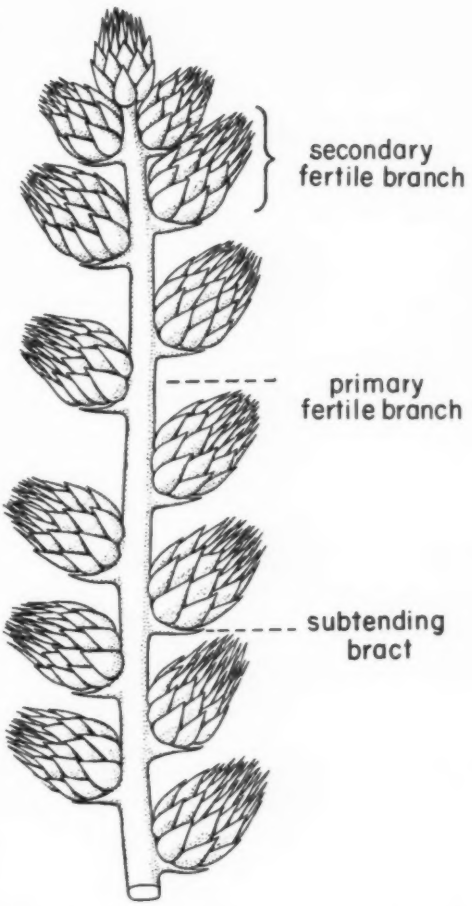
the lack of ovulate cones is due to their maturing in an irregular manner during the life cycle nor that the cone possesses an unusual and unrecognizable form.

Comparisons and trends.—Renault (1879) described *Cordaitanthus penjoni, C. saportanus* and *C. subglomeratus,* three male cordaitean cones from the Stephanian (Upper Carboniferous) at St. Étienne, France. At the time he stated that he had discovered six species of male *Cordaitanthus* in the silicified nodules from St. Étienne but the balance was never described.

Florin (1938–45) in a restudy of this material and further collections of his own at St. Étienne added no new species. The writer examined all of the material (both in the Florin and Renault collections) and is in agreement with the published conclusions as to the distinctiveness of the first two species. *Cordaitanthus subglomeratus* however appears to be a juvenile form and not a good species. *Cordaitanthus shuleri* and the writer's new species *C. compactus* and *C. thompsoni* from the Desmoinesian (Middle Pennsylvanian) coal seams of the central United States are older than the species from St. Étienne as is *C. concinnus* described by Delevoryas (1953). Scott (1919) described fertile shoots of *Mesoxylon multirame* from the Lower Coal Measures at Shore, Littleborough, which are lower Upper Carboniferous in age. These specimens are, therefore, among the oldest of the petrified cordaitean cones. Thus the present study while adding new species does not extend the range of petrified *Cordaitanthus.*

Renault (1879) interpreted the male bud-like organs of *Cordaitanthus* (=secondary fertile shoots Text-fig. 1) as compound inflorescences. He believed the fertile appendages (microsporophylls) to be borne axillary to the sterile appendages or in some cases terminally on the bud-like organ. The female shoots he likewise considered to be compound and he evolved a rather complex terminology for the axes upon which the ovules are borne.

Schoute (1925), Eltringham (1936) and Florin (1938–45) have shown Renault's interpretation to be invalid, because both the fertile appendages (microsporophylls) and the ovules are borne in the same spiral as



TEXT-FIG. 1.—Reconstruction of the terminal portion of a male cordaitean cone.

the sterile appendages. The bud-like structures (secondary fertile branches) simply bear two kinds of appendages, sterile and fertile. They are simple, not compound structures. Each is borne in the axil of a bract, the expected position for a branch, whether long or dwarf. Thus the cones of the two sexes are completely homologous.

The North American species of *Cordaitanthus* differ from the European species in the morphology of the sterile appendages and in the position and number of sporangia. The fertile appendages of the North American species and the attachment of their microsporangia are less well known however.

The sterile appendages are of two kinds, sheathing and acicular, a distinction not seen in the European forms. In addition the histological details of the American forms are well understood. Whereas the European cones are described chiefly from isolated secondary fertile shoots, the American specimens are based on cones with a number of secondary shoots attached to the axis. The concentration of approximately 40 microsporangia at the apex of the secondary fertile branch in estimated groupings of not more than six per microsporophyll is characteristic of American species.

Cordaitanthus shuleri bears globose, secondary fertile shoots 1 cm. in length in two rows on the axis. They consist of a minimum of 40 and up to 95 sterile appendages which run obliquely upward from their point of attachment. The sterile appendages are closely spaced and completely cover the apex of the secondary fertile shoot. The sporangia of this species are nearly all concentrated at the apex of the secondary fertile branch, with a few found in the lower part of the shoot.

Cordaitanthus thompsoni has secondary fertile shoots approximately 6.8 mm. in length and widely spaced on the primary fertile branch. The number of sterile appendages rarely exceeds 40, and they are loosely spaced in the spiral and, like those of *C. shuleri*, run obliquely upward from their point of attachment. The fertile appendages, numbering sometimes 30–40, are all clustered at the apex of the shoot.

Cordaitanthus compactus bears secondary shoots 1 cm. long in contact with each other on the primary cone axis. These shoots are more or less rectangular in longitudinal section and therefore distinct from the globose shoots of *C. shuleri* and *C. thompsoni*. The sterile sheathing appendages extend perpendicularly from the shoot axis for a short distance before bending abruptly tipward. Sterile appendages number from 30–50. Sex has not been ascertained for this cone.

The interpretation of the cordaite cone is of considerable interest in view of the controversy which raged for many years over the morphology of conifer cones. At the root of the dispute was the question: Why should the male cones be simple when the female cones are compound? Comparative morphology, utilizing particularly vascular anatomy, indicated the compound nature of the female cone. It showed that the units of the female cone are each composed of an ovuliferous scale subtended by a bract. Final acceptance of this interpretation was made almost mandatory by Florin's brilliant exposition of the structure of the female cone in various Paleozoic plants. He showed that the ovuliferous scale, when traced back through geologic time, became a progressively more complex structure easily interpreted as a modified branch subtended by a bract. This reduction series, started in *Cordaites*, apparently is continued in true conifers with two Pennsylvanian genera, *Lebachia* and *Ernestiodendron*. The Upper Permian genera *Pseudovoltzia* and *Ullmannia* illustrate continuing reduction trends. Mesozoic genera such as *Voltziopsis*, *Glyptolepis*, *Voltzia*, *Schizolepis*, *Cheirolepis* and *Hirmerella* show varying degrees of reduction and modification culminating in the extant coniferous cone.

Wilde (1944) using the evidence from *Podocarpus* shows how the male conifer cone can be considered basically compound.

The results of such a reduction series illustrate how one male pine cone is homologous to one ovuliferous scale of a female cone. Thus we see two distinct kinds of reduction in the two sexes, reduction of the *parts* of the individual secondary fertile shoots in the case of the female cone and reduction of the *number* of fertile shoots in the male cone.

Among the petrified species of male cones there is variation in 1) the number of appendages on the secondary fertile shoot, 2) the number of fertile appendages on the shoot, 3) the number of microsporangia on each fertile appendage, and 4) the location of the fertile appendages.

Cordaitanthus penjoni shows a concentration of fertile appendages at the apex of the shoot but numerous fertile appendages along the shoot as well. *C. shuleri* shows a larger number at the apex and a very small number along the axis. *C. thompsoni*, *C. saportanus* and *C. concinnus* show all fertile appendages concentrated at or near the apex of the shoot.

In *C. penjoni* fertile appendages usually bear six microsporangia. The vascular strand in the appendage forks dichoto-

mously several times in a cruciate manner and an ultimate strand runs to the base of each sporangium (Florin, 1951; figs. 11, 14). These dichotomies occur in a very short distance and all the sporangia are situated at the same level. This situation seems to represent a more advanced condition than that seen in the primitive female fertile appendage of *C. pseudofluitans* where homologous dichotomies are spread out over a considerable distance and the whole structure is much exserted from the shoot. In *C. saportanus*, however, only four or five sporangia occur on the tip of a fertile appendage, and a reduction in the number of dichotomies of the vascular strand results. *C. saportanus* also shows a decrease in total number of appendages on the secondary fertile shoot.

Despite the unfortunate gap in our information on the vascular supply to, and exact seating of, microsporangia on the fertile appendage in *C. shuleri* and *C. thompsoni*, it is tempting to suggest a possible reduction series. *C. penjoni* with numerous appendages, fertile and sterile, along the axis of the fertile branch and with several dichotomies of the vascular supply to the sporangia might represent the most primitive condition. The number of fertile appendages along the sides of the fertile branch of *C. shuleri* is markedly reduced and a concentration at the apex results. In *C. thompsoni* all fertile appendages are concentrated at or near the apex of the shoot, but the total number of appendages is still considerable. In *C. saportanus* there is a decrease in the over-all size of the fertile branch, in the number of its appendages, and in the number of sporangia. These changes are accompanied by a decrease in the number of dichotomies in the vascular supply to the sporangia.

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Thanks are due Dr. H. P. Banks, Department of Botany, Cornell University, Ithaca, New York, for his encouragement and interest during this study.

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ACROCEPHALITES? GLOMERATUS WALCOTT, 1916

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ABSTRACT—The trilobite *Acrocephalites? glomeratus* Walcott, 1916, is made the type of a new genus, *Rawlinsella*. The stratigraphic position of the species, known only from the holotype from Rawlins, Wyoming, is deduced as being near the base of the Buck Spring formation and of latest Middle Cambrian age.

THE species *Acrocephalites? glomeratus* Walcott, 1916, has been a puzzle since the time of its description. The holotype is from USNM Loc. 340c, which Walcott (1916, p. 179) described simply as:

> Upper Cambrian: (340c) Dark reddish brown sandstone, Rawlins, Carbon County, Wyoming.

No stratigraphic position was given, nor were any other fossils associated with the type, so the age and the exact geographic and stratigraphic positions of the species remained unknown.

In an effort to learn more about the species, the type specimen was borrowed, in in 1952, from the U.S. National Museum, through the courtesy of Dr. G. A. Cooper. The matrix was examined by Dr. J. A. Barlow, who was at that time mapping the Rawlins Uplift. From this examination it became clear that the specimens came from the Buck Spring formation. The Buck Spring (Shaw, 1954) is the non-resistant red and tan sand, silt and shale unit that overlies the quartzitic Flathead sandstone in the Rawlins Uplift and elsewhere in south-central Wyoming. At the type locality, at Buck Spring, northwest of Rawlins, the formation is 104 feet thick, but toward the southeast the formation thins and is only 6 feet thick at Rawlins. A discussion and description of the fossils collected from the type section will be given in a later article, but the lower 30 feet of the section have yielded *Olenoides* sp. indet., *Bolaspis* (or *Bolaspidella*) n. sp., and *Lingulepis acuminatus*. This scant faunule plus regional stratigraphic evidence suggests a late Middle Cambrian age for these beds.

If the lower Buck Spring is Middle Cambrian, the stratigraphic position of "*Acrocephalites*" *glomeratus* relative to these beds must be determined; unfortunately, there is no direct evidence. The crux of the problem is whether the "Rawlins" mentioned by Walcott in the description of USNM Loc. 340c means the town of Rawlins itself or the Rawlins area in general. This is critical because the Buck Spring formation, from which the type seems to have come, is thin at Rawlins, but thicker elsewhere, and if the type is from Rawlins its stratigraphic position can be fixed rather precisely. Two lines of evidence suggest that the type did come from Rawlins:

The first line of reasoning is more or less historical and runs thus: First, the collector of the type was apparently not Walcott, the describer, for he seems not to have worked in the Rawlins area; some other member of the U. S. Geological Survey staff must have picked up the specimen. Second, this worker probably was in the vicinity of Rawlins itself, for early Survey interest in the area was not in the entire uplift but in the area around Rawlins where hematite deposits were being mined. Third, if the specimen had come from the thicker part of the Buck Spring in the northwestern part of the uplift the locality name given more likely would have been "Belle Springs" or "Buck Spring" than "Rawlins." Fourth, the failure of Survey publications on the northwestern part of the uplift to mention the existence of the only named species from the region suggests that these workers were ignorant of it, which they would not have been if they had collected the specimens. This evidence is admittedly inferential, but it seems in aggregate to suggest that the type of "*Acrocephalites*" *glomeratus* came from near the town of Rawlins.

The second line of evidence concerns the matrix in which the type is preserved: The holotype is an internal mold in dark-red-stained sandstone; this type of staining is found widely through the Buck Spring formation, but it is far more common near Rawlins, where the commercial hematites have developed, than elsewhere.

If these two lines of evidence are admitted to show that the type came from near Rawlins, the stratigraphic position must be in the lower 25 feet of the Buck Spring, for that formation is eroded to that thickness or less around Rawlins. This lower part of the section is that which has yielded the late Middle Cambrian faunule at Buck Spring.

A third line of evidence that supports the inference that the specimen is from the basal beds of the Buck Spring, regardless of its geographic origin, is that the Buck Spring itself may be non-marine above the lower 30–50 feet. No fossils have been seen in the upper beds in any exposure visited in the uplift, and silt casts of salt crystals are locally developed in the southeastern part of the uplift.

In summary, all evidence seems to suggest a stratigraphic position in the lower 25 feet of the Buck Spring formation for "*A.*" *glomeratus* and to suggest that this level belongs in the upper Middle Cambrian.

The generic assignment of this species has also been long in doubt. Assigned provisionally to *Acrocephalites* by Walcott because of the median boss on the brim, the species was later moved to *Modocia* by Resser, but the median boss is not here regarded as a feature admissible to *Modocia*. During preliminary studies for this note "*A.*" *glomeratus* was tentatively assigned to *Alokistocare*, but the convex, even border eliminates it from that genus, although it may possibly be congeneric with some of the species assigned to *Alokistocare* by Resser. Thus, it is clear that "*A.*" *glomeratus* does not fit well into previously named genera, so the new genus *Rawlinsella* is erected for it.

RAWLINSELLA n. gen.

Description.—Genus known only from cranidium, which is slightly transverse. Glabella conical, with a squared front. Dorsal furrows well marked all around, with pits at the antero-lateral angles of the glabella. Occipital furrow shallow; occipital ring not preserved. Brim about half as long as border, with a well developed median boss. Border widest in the middle, tapering toward a vanishing point in line with the palpebral lobes. Palpebral lobes are not preserved, but they lay forward of the midpoint of the glabella (excluding the occipital ring); fixed cheeks convex and raised to half the height of the glabella above the dorsal furrows, nearly flat on top. Posterior limbs marked by an open marginal furrow; limbs slightly narrower than the occipital ring.

Type species.—*Acrocephalates? glomeratus* Walcott, 1916.

RAWLINSELLA GLOMERATA (Walcott), 1916

Pl. 9, fig. 7–9

Acrocephalites? glomeratus WALCOTT, 1916, Smithsonian Misc. Coll., vol. 64, no. 3, p. 179, pl. 26, fig. 7, 7a.

Modocia glomerata (Walcott). RESSER, 1935, Smithsonian Misc. Coll., vol. 93, no. 5, p. 42.

Modocia glomerata (Walcott). THOMAS, 1951, Wyoming Geol. Assoc. 6th Ann. Field Conference Guidebook, p. 32.

The principal features of the species have been outlined above. The coarse sand preservation of the holotype makes it impossible to be sure whether there were glabellar furrows.

Following are the dimensions of the holotype: sagittal length of the cranidium from the occipital furrow to the anterior margin, 14.5 mm.; sagittal distance from the occipital furrow to the marginal furrow, 12.0 mm.; sagittal length of the glabella, excluding the occipital ring, 9.0 mm.; distance, measured in the sagittal plane, from the occipital furrow to the estimated center of the palpebral lobes, 5.7 mm.; estimated width of the cranidium between the outer tips of the posterior limbs, 17 mm.; estimated width of the cranidium between the centers of the palpebral lobes, 20.4 mm.; maximum transverse width of the border, 15.4 mm.; width of the occipital ring, measured between the deepest points in the dorsal furrow on either side of the ring, 8.1 mm.; width of the glabella, similarly measured, opposite the centers of the palpebral lobes, 7.0 mm.; length of the chord of the posterior limb, 7.1 mm.

Holotype.—USNM 61591 (casts UW IT-256).

Paratypes.—Apparently missing.

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A CAMBRIAN *APHELASPIS* FAUNA FROM STEELE BUTTE, NEAR BOULDER, WYOMING

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ABSTRACT—A fauna representing the *Aphelaspis* zone (upper Dresbachian) from the base of the Dry Creek shale at Steele Butte, near Boulder, Wyoming, contains the trilobites *Raaschella occidentalis* Lochman, 1944, *Aphelaspis walcotti* Resser, 1938, and *Cheilocephalus delandi*, n. sp.; the gastropods *Hypseloconus simplex simplex* Lochman, 1944, and *H. simplex erectus*, n. subsp.; and the problematical fossil *Pseudomatthevia conica*, n. gen., n. sp.

THE only exposures of Cambrian rocks on the west-central flank of the Wind River Mountains lie a short distance southeast of the town of Boulder, Wyoming, in secs. 7, 19, 20, 29, and 30, T. 32 N., R. 107 W., and in secs. 1 and 12, T. 32 N., R. 108 W., Sublette County. The exposures in secs. 19, 20, 29 and 30, T. 32 N., R. 107 W. form a prominent hill called Steele Butte. The geology of this area has been described by Love (1950, p. 25–27). The Cambrian section has been measured by C. R. DeLand (Shaw and DeLand, 1955), and his summary of the Upper Cambrian faunas, except those of the *Aphelaspis* zone, will appear in a later issue of this journal.

The present collections were made in June, 1951, by E. F. Durkee, Harold Falzone, W. W. Gibson, and A. B. Shaw from the north end of Steele Butte and were taken from the Dry Creek shale (see Locality Register below). DeLand measured a section slightly farther south in the Butte and did not find the *Aphelaspis* faunas indicating that they are preserved as a pod not removed by pre-*Elvinia* erosion.

ACKNOWLEDGMENTS

The cost of printing the photographs on the accompanying plates was defrayed by the Wyoming Geological Survey, and part of the cost of publishing the plates was met by a grant-in-aid from the Graduate Research Council of the University of Wyoming.

LOCALITY REGISTER

Four thin beds of limestone yielded fossils on Steele Butte. The three lowest contain the fauna described here, and the fourth contains an *Elvinia* zone fauna.

Loc. 32107/20A8. Dry Creek shale, 64 feet above the base in SE¼, sec. 19. Fauna:

Elvinia zone fauna (not described)

Loc. 32107/20A5. Dry Creek shale, 11½ feet above the base in SW¼, sec. 20. Fauna:

Cheilocephalus delandi (5 cranidia; 5 pygidia)

Raaschella occidentalis (1 cranidium)

Aphelaspis walcotti (1 cranidium)

Loc. 32107/20A4. Dry Creek shale, 10 feet above the base in SW¼, sec. 20. Fauna:

EXPLANATION OF PLATE 9

Acrocephalites? glomeratus Walcott, 1916; by Alan B. Shaw.

FIG. *7–9*—*Rawlinsella glomerata* (Walcott), 1916. Antero-dorsal, dorsal and anterior views of the holotype cranidium. Basal (?) Buck Spring formation, "Rawlins" (USNM Loc. 340c). USNM 61591. Photographs by E. F. Durkee. (p. 47)

A Cambrian *Aphelaspis* fauna from Steele Butte, near Boulder, Wyoming; by Alan B. Shaw

FIG. *1–6*—*Aphelaspis walcotti* Resser, 1938. *1*, Cranidium 10 mm. long. One foot below top of Du Noir limestone, Beaver Creek UW A11157a. *2, 3*, Dorsal and anterior views of cranidium 5 mm. long preserving palpebral lobe. Dry Creek shale, 11½ feet above base, Steele Butte. UW A11167. *4–6*, Anterior, lateral and dorsal views of cranidium 3.8 mm. long. Cranidium of *Raaschella occidentalis* partly exposed beneath left palpebral lobe. Dry Creek shale, 3½ feet above base, Steele Butte. UW A1294. (p. 51)

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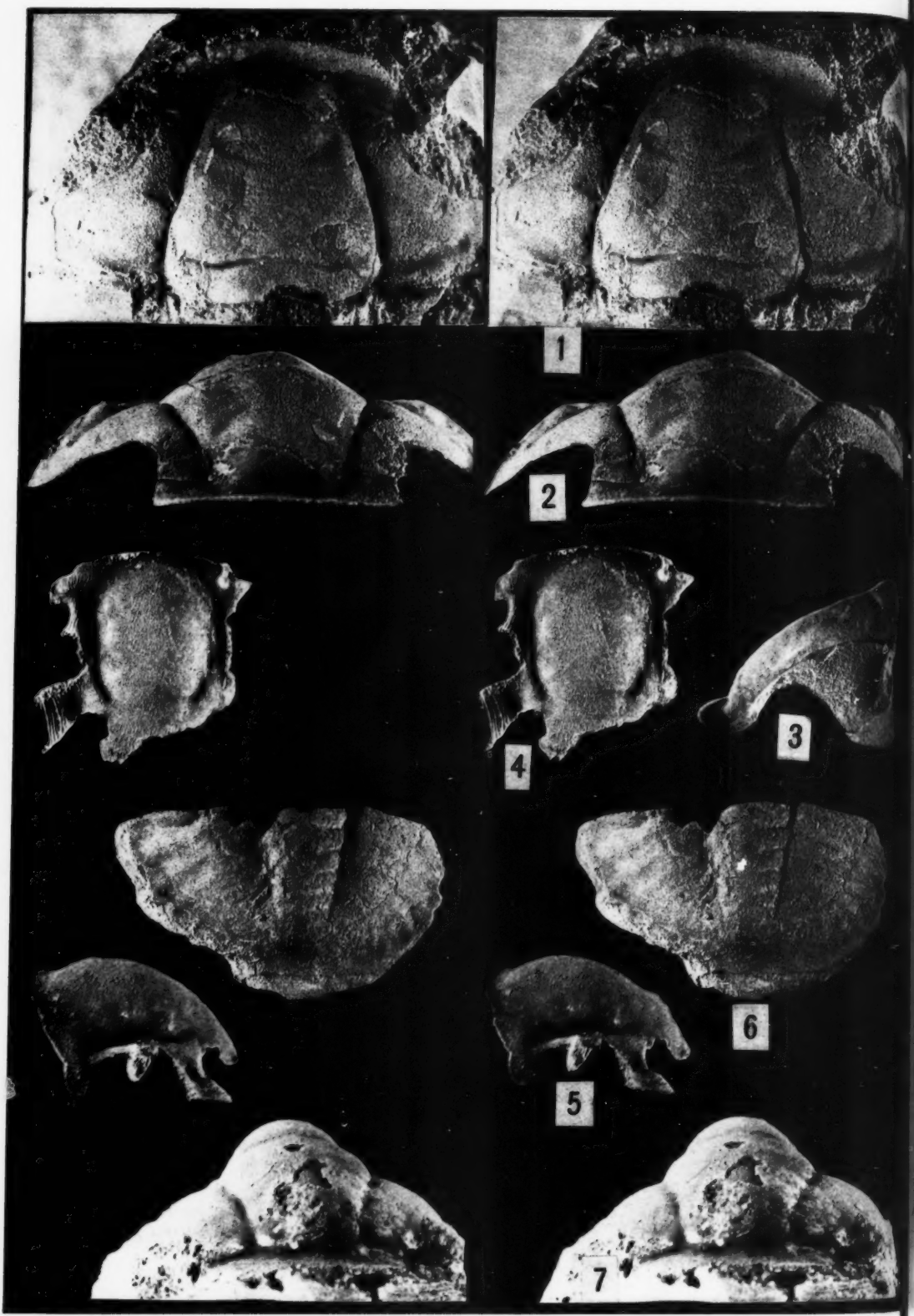
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Cheilocephalus delandi (84 cranidia; 77 pygidia; 2 hypostomata)
Hyseloconus simplex simplex (6 shells)
Pseudomatthevia conica (2 shells; 1 operculum)

Loc. 32107/20A2. Dry Creek shale, 3½ feet above the base in SW¼, sec. 20. Fauna:
Cheilocephalus delandi (46 cranidia; 50 pygidia; 1 hypostoma)
Raaschella occidentalis (7 cranidia)
Aphelaspis walcotti (1 cranidium)
Hypseloconus simplex erectus (13 shells)
Pseudomatthevia conica (1 fragmentary shell)

ORIGIN OF THE FOSSIL DEPOSIT

As the fossil lists given above show, the Steele Butte beds are prolific of individuals, but the variety of species is small. This sort of deposit immediately suggests a cold-water fauna, which is in keeping with the composition of the *Aphelaspis* zone faunas elsewhere. The fossils are unbroken and are found randomly oriented in light brown crystalline limestone, in beds 1–4 inches thick, interbedded with Dry Creek shale, but the lack of free cheeks, thoracic segments and hypostomata suggests that the deposit is a current-formed accumulation of shells and not a biocoenose. It appears that the convex, and therefore more buoyant, parts of the trilobites, together with the shells of *Hypseloconus* and *Pseudomatthevia* have been accumulated in large numbers, leaving behind the flatter parts of the trilobite tests. In this connection it is interesting to note that Lochman (in Lochman & Duncan, 1944, p. 80), in her description of *Hypseloconus parvicostatus*, also expressed the view that her specimens from the *Cedaria* zone in the Pilgrim limestone had been transported out of their original environment. The Steel Butte deposit suggests that same thing.

Lochman & Duncan (1944, p. 31–32) have discussed the *Aphelaspis* fauna and have noted that it is small in number of species, restricted in areal development in any given region, and apparently of normal marine facies. All of these peculiarities are again shown at Steel Butte.

SYSTEMATIC PALEONTOLOGY

TRILOBITA

Family CHEILOCEPHALIDAE, n. fam.

The genus *Cheilocephalus* seems sufficiently distinct from other trilobites to bar admission to any named family. The large tail and the general cranidial configuration suggest association with the large group of asaphiscid trilobites, but, in detail, the structure is anomalous.

The new family Cheilocephalidae may be defined as containing asaphiscid (?) trilobites with small, anteriorly placed eyes, a concave frontal area, and apparently proparian facial sutures. The only included genus is *Cheilocephalus* Berkey, 1898.

CHEILOCEPHALUS DELANDI, n. sp.

Pl. 10, 11; Pl. 12, fig. 1, 6

Cranidium.—Cranidium transverse; largest specimen 31 mm. across the posterior limbs and 16 mm. long, axially. Convexity moderate in juveniles and young adults but considerably reduced in large specimens.

Glabella truncato-conical, moderately convex except in the largest specimens, and slightly keeled. Glabellar furrows absent, faint, or rarely shallow, varying from one individual to another, not ontogenetically; furrows poorly impressed on internal impressions; anterior pair, where present, are straight, posteriorly deflected notches; pos-

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EXPLANATION OF PLATE 10

Cheilocephalus delandi, n. sp., all from Loc. 32107/20A4. (p. 49)

FIGS. *1–3*—Holotype cranidium. UW A10204a. Width of occipital ring 14.4 mm.
4, 5—Assigned hypostoma, ventral and antero-lateral views to show the dorsally deflected anterior wings. UW A10204q. Maximum width of middle body 3.7 mm.
6—Largest pygidium obtained; somewhat weathered. UW A10204k. Axial length 17.5 mm.
7—Medium sized cranidium, anterior view, showing greater convexity of smaller individuals. Compare with fig. 2 above. Angulations on the border of the posterior limbs not preserved. Width of anterior end of glabella 3.9 mm.

terior pair slightly bowed. Occipital furrow deflected forward in the middle, narrow, and obsolete mesially in some specimens, although it is complete but shallow mesially in others. Occipital ring slightly widened in the middle because of the bowing of the occipital furrow; slightly convex longitudinally. Dorsal furrows narrow but not deep and not impressed in front of the glabella.

Frontal limb deeply concave, not divided into brim and border. Frontal limb set off from the fixed cheeks by an abrupt downslope in front of inconspicuous ocular ridges. Fixed cheeks slightly downsloping, gently convex in all directions. No palpebral furrow. Cheeks about one-third the width of the glabella opposite the eyes at all known stages of growth, but they appear to be proportionately a little wider in younger specimens. Palpebral lobes small, short, oblique and virtually undifferentiated from the fixed cheeks; situated opposite the first glabellar furrows and the anterior third of the glabella. Posterior limbs narrower than the occipital ring, downsloping, marked by shallow marginal furrows, which turn anteriorly on the outer third of the limb. Prominent angulations mark the posterior border of the limb one-third of the way to the tip.

Surface smooth.

Hypostoma.—Three fragmentary hypostomata are associated with the cranidia of this species. The anterior margin is slightly curved. The anterior border is narrow and concave (as viewed from the ventral side) and grades into the middle body without a break. Laterally, the anterior wings are bent dorsally to form an angle of about 75° with the plane of the hypostoma (projected); this deflection is unusual and suggests a rigid connection with the doublure. Middle body tumid and set off by lateral furrows. Middle furrows short. No maculae observed. Posterior and postero-lateral borders not preserved.

Free cheek.—None seen.

Pygidium.—The pygidium is semi-circular and rather smooth in most specimens, although individuals vary considerably in their degree of effacement. The incision of the furrows is not an ontogenetic variable, for the largest and third smallest pygidia are furrowed, and both smooth and furrowed types appear at random throughout the series when the specimens are arranged according to size. Adult pygidia about 18 mm. long show 7 segments plus the articulating half-ring and a terminal segment on the axial lobe, although smooth individuals commonly show only 5–6 rings. Smaller pygidia 6–8 mm. long show a variation in the number of rings (5–7), but apparently the variation is not closely connected with pygidial length; a statistical study of this variation will be presented elsewhere. Dorsal furrows are faint laterally and absent at the rear of the axial lobe, which blends with the steeply downsloping outer edge of the pleural platform. Pleural platform horizontal when viewed from the rear but sloping posteriorly in lateral view; unfurrowed in many specimens, but on internal molds and furrowed exteriors 4–6 pleural segments are visible. The segments are swept back, forming an angle of about 60° with the axial lobe. Pleural furrows and interpleural grooves about equal in width and shallow, making distinction between them difficult. Anterior marginal furrow well incised, cutting off an angulated pleural border. Margin roughly as wide as the pleural platform, deeply concave in the young, only slightly so in the adults (compare fig. 1 and 6, Pl. 12). Ridges extending from the anterior edge of each pleural segment flare out onto the margin, giving it a "washboard" surface. No recognizable border. Average size of largest specimens when complete, 20 mm. long and 30 mm. wide, with the axial lobe 9–10 mm. wide anteriorly.

Remarks.—Palmer (1955, p. 757–759) has thoroughly discussed *Cheilocephalus* and suppressed *Pseudolisania raaschi* and *P. texana* both of Lochman, 1938, as synonyms of *Cheilocephalus brevilobus* (Walcott), 1916. Under such a broad interpretation of this species it is possible that *C. delandi* would be regarded as no more than a geographical variant of *C. brevilobus*, but the Wyoming form differs in two respects which, though small, appear to be constant. First, the pleural platforms of the pygidium do not slope down laterally but are horizontal and, at comparable sizes, form a more transverse triangle than those on *C. brevilobus*. Second, the axial lobe of the pygidium is relatively

shorter, as compared to the length of the pygidium, than in *C. brevilobus.*

Distribution.—Present in all three collections at Steele Butte but unknown elsewhere.

Holotype.—UW A10204a from Loc. 32107/20A4

Paratypes.—UW A11165 and A11166 (Loc. 32107/20A2); UW A10204 and A11206 (Loc. 32107/20A4); UW A11171 (Loc. 32107/20A5).

Family PTYCHOPARIIDAE Matthew, 1888

APHELASPIS WALCOTTI Resser, 1938

Pl. 9, fig. 1–6

Aphelaspis walcotti Resser. PALMER, 1955, Jour. Paleont., vol. 28, p. 746, pl. 84, fig. 2, 4–8. Full synonymy to date.

Palmer has thoroughly discussed this species and has noted its occurrence in the "Gallatin" (=Dry Creek shale or DuNoir limestone) of Wyoming. The specimens from Steele Butte show a more tapering glabella than those figured by Palmer, but specimens from the Dresbach formation at Nigger Coulee, Hudson, Wisconsin, show both glabellar shapes, suggesting intraspecific variability in this feature.

Distribution.—Widely distributed through the *Aphelaspis* zone of the United States (see Palmer, 1955, p. 746–747). Known also from Wyoming at Beaver Creek, sec. 1, T. 29 N., R. 98 W., Fremont County, one foot below the top of the DuNoir limestone; a specimen from this locality is figured for comparison (Pl. 9, fig. 1).

Plesiotypes.—UW A1294 (Loc. 32107/20A2) and UW A11167 (Loc. 32107/20A5).

Family SOLENOPLEURIDAE Angelin, 1854 (sensu lato)

RAASCHELLA OCCIDENTALIS Lochman, 1944

Pl. 12, fig. 4, 5

Raaschella occidentalis LOCHMAN in Lochman & Duncan, 1944, Geol. Soc. Am. Special Paper 54, p. 43–44, pl. 4, fig. 1–5.

The specimens from Steele Butte can add little to the very thorough original description of this species. The specimens from Wyoming seem to have their furrows more deeply incised than do those from Montana.

Distribution.—Originally described from the *Aphelaspis* zone of the Pilgrim limestone of Nixon Gulch, Montana. Present in the top and bottom beds at Steele Butte.

Pleisotypes.—UW A5, A1294 and A11166 (Loc. 32107/20A2) and UW A11145 (Loc. 32107/20A5).

GASTROPODA

Family HYPSELOCONIDAE Knight, 1952

HYPSELOCONUS SIMPLEX SIMPLEX Lochman, 1944

Pl. 12, fig. 7; Pl. 13, fig. 3

Hypseloconus simplex LOCHMAN in Lochman & Duncan, 1944, Geol. Soc. Am. Special Paper 54, p. 42, pl. 4, fig. 6.

This species has been fully described by Lochman, and the specimens from Steele Butte show no new features.

Remarks.—Because of the erection of the new subspecies *H. s. erectus* for the older form of *H. simplex* it is necessary to designate the typical subspecies *H. simplex simplex.* The differences between the two subspecies, while distinctive, do not now seem sufficiently great to warrant full specific separation.

Distribution.—Originally described from the *Aphelaspis* zone of the Pilgrim limestone of Nixon Gulch, Montana. Present in the middle bed at Steele Butte.

Pleisotypes.—UW A11164 and A11206 (Loc. 32107/20A4).

HYPSELOCONUS SIMPLEX ERECTUS, n. subsp.

Pl. 12, fig. 2, 3

Diagnosis.—This subspecies differs from *H. simplex simplex* in being smaller in average size and in being less curved in lateral aspect; the latter feature suggested the subspecific name.

Distribution.—Confined to the lowest bed at Steele Butte.

Syntypes.—UW A11162 (Loc. 32107/20A2).

Problematicum

Genus PSEUDOMATTHEVIA, n. gen.

Description.—Shell conical and operculate. Sides of the shell straight, forming an angle of 65°–70°. Height of cone estimated 20–25 mm.; no specimen is complete. Transverse outline slightly ovate, with the shorter and longer diameters as 8 is to 9 or as 8 is to 10. The cone is marked by broad, shallow undulations that seem to run around the

cone, but poor preservation makes it impossible to be sure that these undulations are not slightly inclined.

Operculum known only from an internal mold; it is a low cone with an apical angle of about 110°–115°. Outline subovate to fit the shell. Surface apparently smooth except for a broad, shallow groove running down one side parallel to the shorter diameter of the oval; this groove may possibly represent a muscle attachment on the inside of the operculum.

Remarks.—This species was at first thought to belong to *Matthevia* Walcott, 1885, but cracking of the larger paratype (Pl. 13, fig. 4, 5) showed that there is nothing comparable to the internal process of *Matthevia* in this shell. The similar external appearance of the two genera leads to the name *Pseudomatthevia* for this animal. Like *Matthevia*, there is little to indicate the biologic affinities of this form and other conical Cambrian shells so the new genus is placed under the heading of "Problematicum."

Genotype.—*Pseudomatthevia conica* Shaw, n. sp.

PSEUDOMATTHEVIA CONICA, n. sp.
Pl. 13, fig. 1, 2, 4–7

Inasmuch as no similar fossils are known, it is impossible to separate the specific and generic features, and both are included in the description given above.

Distribution.—Known only from the two lower beds at Steele Butte.

Holotype.—UW A11204a (Loc. 32107/20A4).

Paratypes.—UW A11204b, c (Loc. 32107/20A4) and UW A11169 (Loc. 32107/20A2).

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MANUSCRIPT RECEIVED JULY 13, 1955

EXPLANATION OF PLATE 11

Cheilocephalus delandi, n. sp. (p. 49)

FIG. *1*—Large, unexfoliated pygidium; break in posterior margin exposes impression of the doublure. UW A10204l. Loc. 32107/20A4. Width of third axial segment 7.3 mm.

2—Small, nearly complete, smooth pygidium. UW A11165f. Loc. 32107/20A2. Maximum width 7.6 mm.

3—Small, nearly complete pygidium, showing wide margin behind axial lobe. UW A10204i. Loc. 32107/20A4. Maximum width 7.3 mm.

4–6—Normal, medium sized pygidium. UW A11165c. Loc. 32107/20A2. Maximum width 15.9 mm.

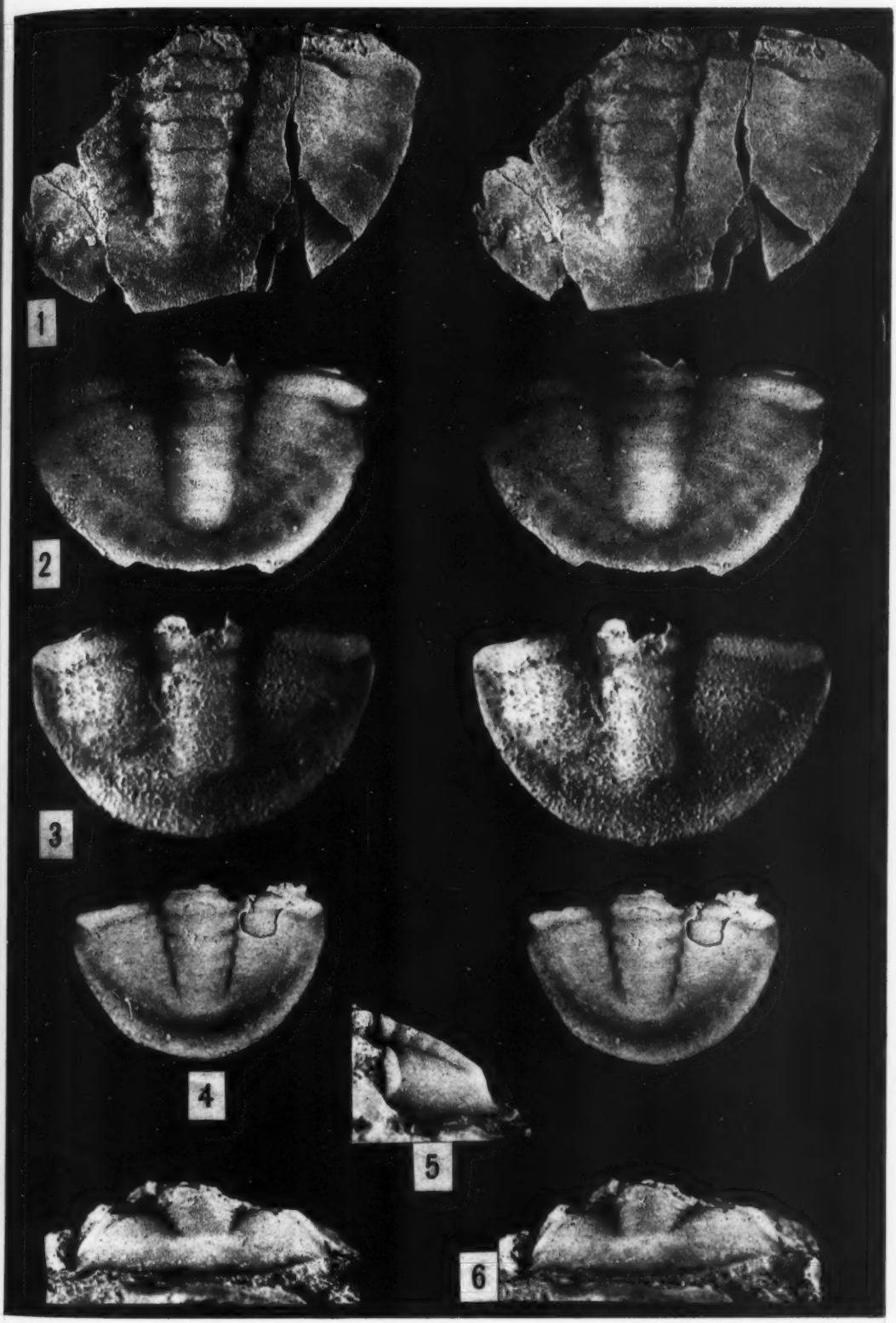
EXPLANATION OF PLATE 12

FIG. *1, 6*—*Cheilocephalus delandi*, n. sp. *1*, Fragmentary cranidium showing an uncommon, sinuous pattern of the dorsal furrows. UW A10204d. Loc. 32107/20A4. Length of glabella, including occipital ring 7.7 mm. *6*, Small cranidium of typical configuration; like specimen shown on Pl. 10, fig. 7. UW A10204b. Loc. 32107/20A4. Axial length 7.1 mm. (p. 49)

2, 3—*Hypseloconus simplex erectus*, n. subsp. *2*, Best preserved specimen, a steinkern showing muscle scars. Height perpendicular to broken base 10.5 mm. *3*, Lateral view of fragment showing erect shape (compare with figure 7, this plate). Maximum height 12.5 mm. Both specimens: UW A11162 from Loc. 32107/20A2. (p. 51)

4, 5—*Raaschella occidentalis* Lochman, 1944. Best preserved cranidium, dorsal and lateral views. UW A11166a. Loc. 32107/20A2. Axial length 2.3 mm. (p. 51)

7—*Hypseloconus simplex simplex* Lochman, 1944. Lateral view of internal mold. UW A11166a. Approximately ×2. (p. 51)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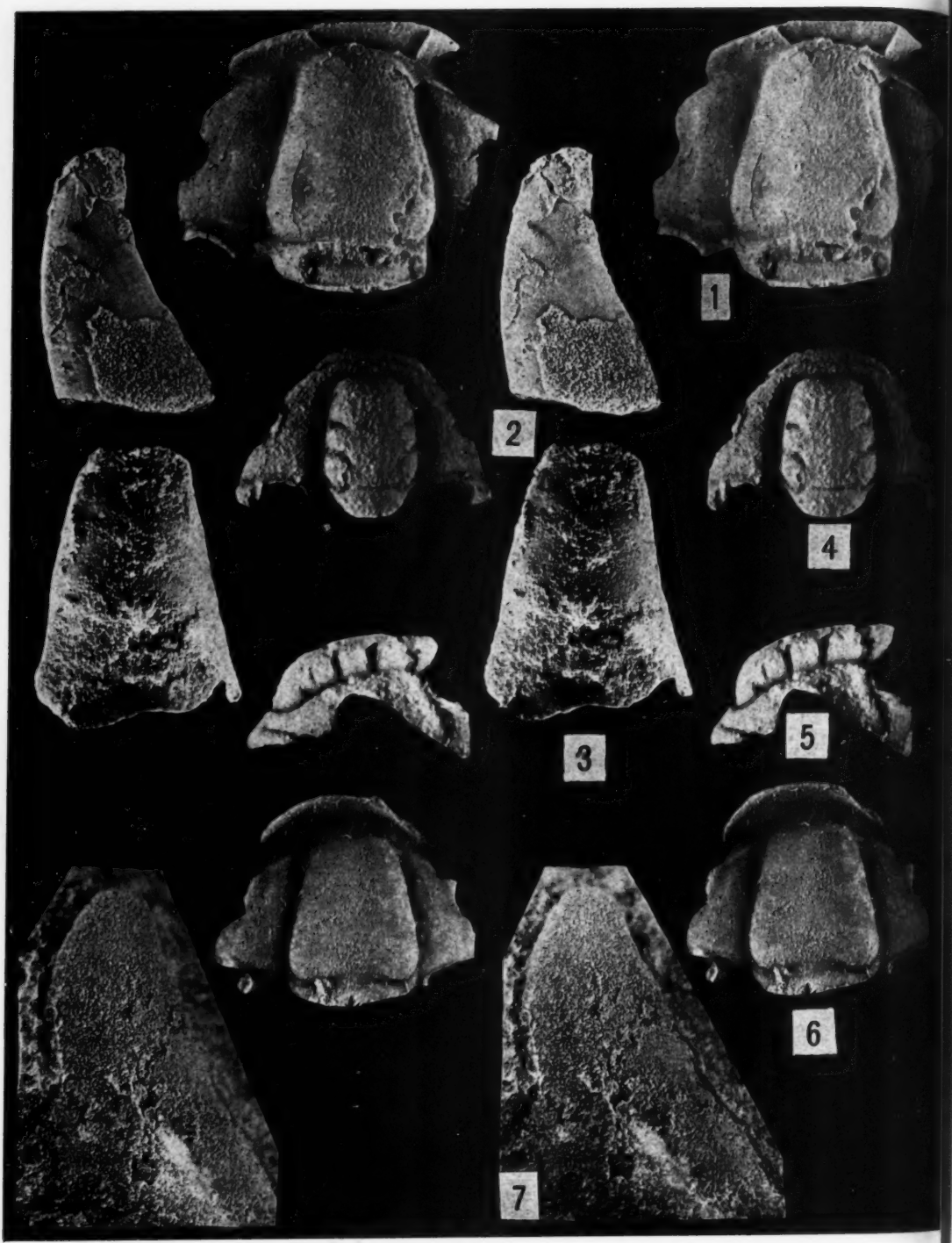
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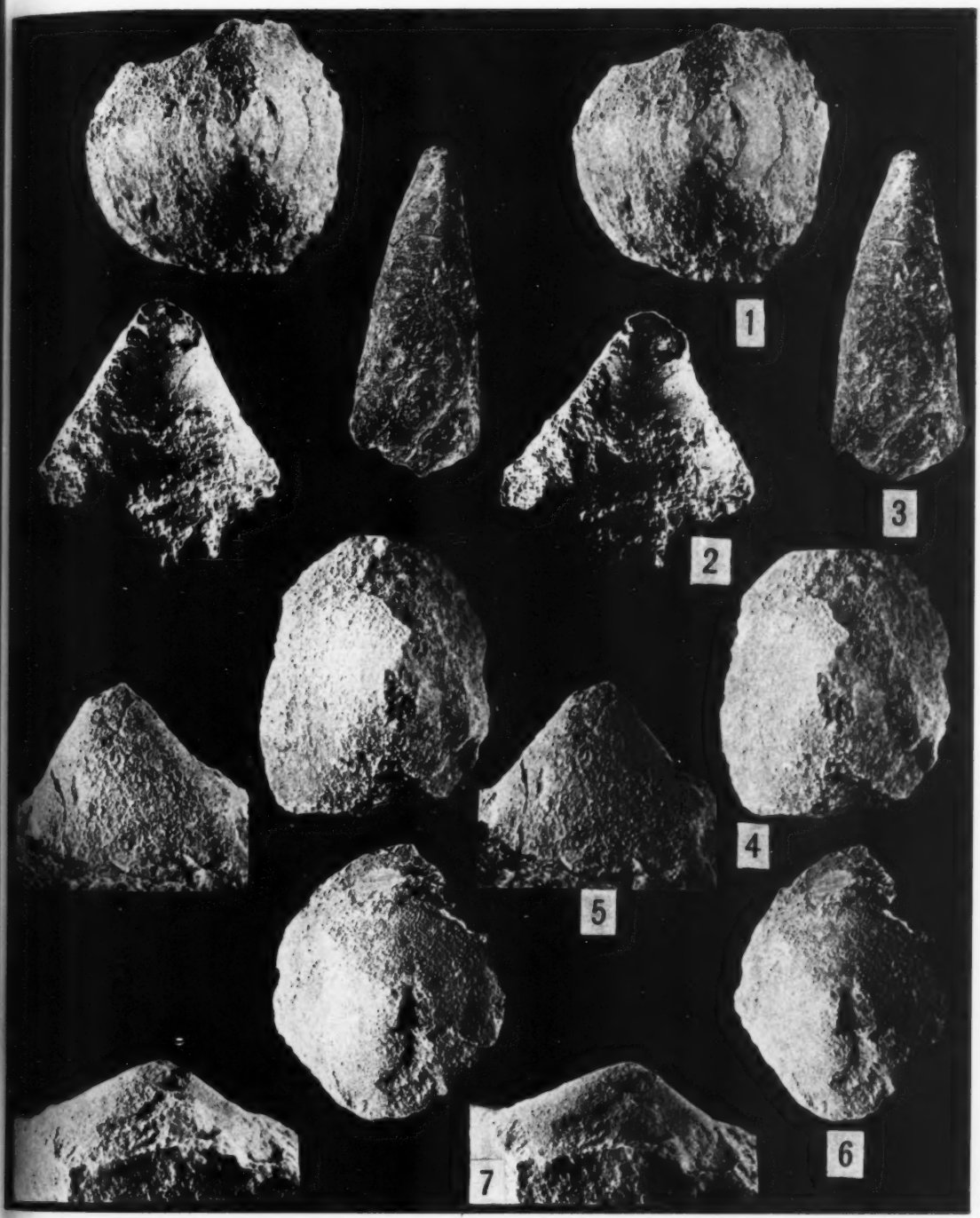
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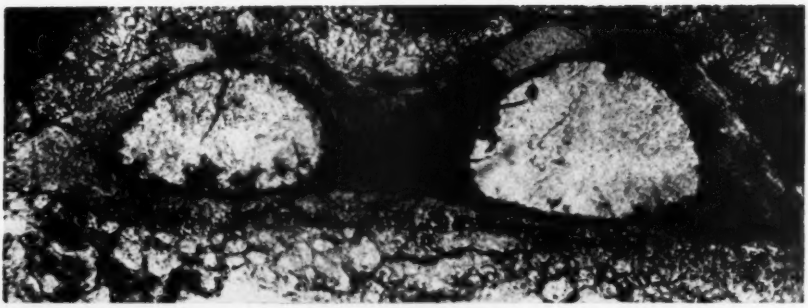

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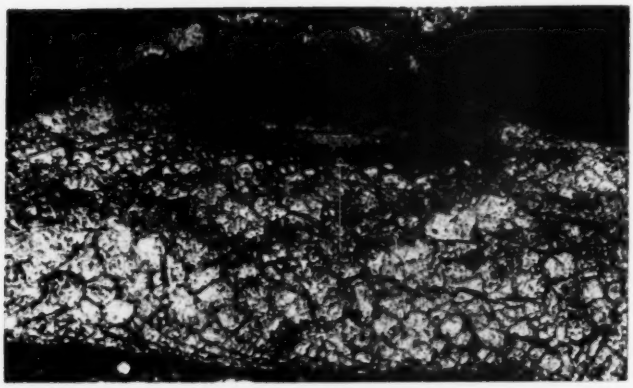

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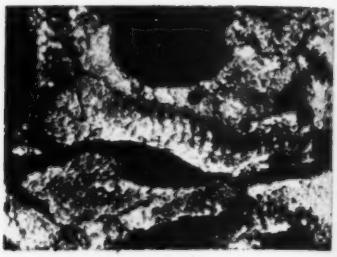

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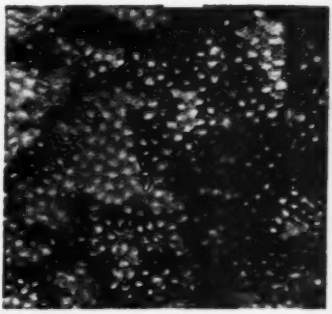

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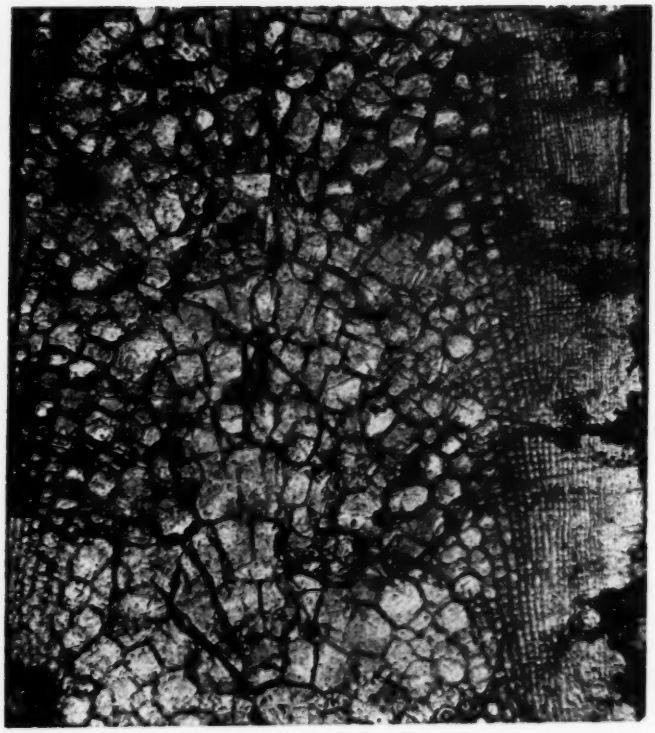

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Johnson, New Paleozoic coralline algae

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 53–55, PL. 14, JANUARY 1956

ARCHAEOLITHOPHYLLUM, A NEW GENUS OF PALEOZOIC CORALLINE ALGAE

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ABSTRACT—A new genus, *Archaeolithophyllum*, is erected to contain two new species of Pennsylvanian coralline algae from the mid-continent region: *A. missouriensum* (type species) and *A. delicatium*. The genus most closely resembles the Recent genus *Lithophyllum*.

INTRODUCTION

IN 1946, John Kay of Wichita Falls, sent the writer a sizeable collection of Pennsylvanian and Permian algal limestones from the Wichita Falls Region of Texas. Additional specimens were sent by him at intervals during the next seven years. A study of the material revealed a number of types of algae including a form having structure features surprisingly similar to those found in the modern genus *Lithophyllum*. Unfortunately the preservation was poor, the algae being replaced by iron oxide, so a descritpion of the material was postponed until better material could be obtained.

Late in 1953, Walter V. Searight of the Missouri Geological Survey, submitted specimens of similar algae and commented that they were widespread in the Pennsylvanian of Missouri. In 1954, Wallace B. Howe, also of the Missouri Geological Survey, contributed additional material from Missouria and Illinois. Some of these specimens were exceptionally well preserved, permitting a detailed study and description of the algae.

Thanks are due these three contributors for supplying the material. The Colorado School of Mines furnished laboratory facilities and supplies.

The type and figured specimens, belonging to the Missouri Geological Survey, are deposited with the U. S. Geological Survey at the Denver Federal Center as Fossil Algae Nos. 324, 325, 326, and 327.

EXPLANATION OF PLATE 13

FIG. *1*, *2*, *4–7*—*Pseudomatthevia conica* n. gen., n. sp. *1*, *2*, Holotype shell, UW A11204a. Width of shell, in profile shown in figure 2, 23.9 mm. *4*, *5*, Paratype shell. UW A11204b. Width as above 17.4 mm. *6*, *7*, Internal impression of an operculum. UW A11204c. Width perpendicular to the notch 14.7 mm. All specimens from Loc. 32107/20A4. (p. 52)

3—*Hypseloconus simplex simplex* Lochman, 1944. Anterior view of well-preserved shell. UW A11164b. Approximately ×2. (p. 51)

EXPLANATION OF PLATE 14

Archaeolithophyllum missouriensum, n. sp. (p. 54)

FIG. *1*—View of a portion of the type (×50) showing two conceptacles surrounded by perithallic tissue and a little hypothallic tissue. Carroll County, Missouri (U.S.G.S. type algae No. 324).

2—Another portion of the type (×50) showing the large hypothallus, with the arched layers of large cells, and a v ery narrow marginal perithallus which thickens around a conceptacle. (The conceptacle is cut considerably off center.)

3—Section of a large specimen (×50) showing details of structure of the hypothallus and perithallus. Collinsville, Illinois. (U.S.G.S. fossil algae No. 326).

5—A section parallel to the top surface (×100) showing the perithallic cells. (Section is perpendicular to the one shown as figure 3.) Collinsville, Illinois (U.S.G.S. specimen No. 327).

Archaeolithophyllum delicatium, n. sp. (type specimen, somewhat recrystallized). (U.S.G.S. type algae No. 325.) (p. 55)

FIG. *4*—A portion of the type specimen (×50) showing coaxial hypothallus.

6—Another portion of the type (×50) showing a very highly arched conceptacle chamber with suggestions of a single large pore.

Distribution.—These algae occur abundantly in limestones of Pennsylvanian age over wide areas in the mid-continent region. Specimens were studied from the following localities:

Breckenridge limestone, McConn Bridge, Young County, Texas (John A. Kay, 1946).

Lower Crystal Falls limestone, Rattler Branch, New Castle-Eliasville Road, Young County, Texas (John A. Kay, 1953).

Tiawah limestone, Montrose, NW¼ NE¼ Sec. 11, T. 40 N., R. 28 W., Henry County, Missouri (Walter V. Searight, 1953).

Tiawah limestone, Mullani Mine, N. E. of Liberal, NE¼ NW¼ Sec. 28, T. 33 N., R. 32 W., Barton County, Missouri (Walter V. Searight).

Exline limestone (type locality for *Archaeolithophyllum missouriensum*), near Coloma, Carroll County, Missouri. South bank of creek, SE¼ NW¼ Sec. 34, T. 55 N., R. 24 W. (Wallace B. Howe, 1953).

Exline limetsone, Sullivan County, Missouri. Road cut, south of bridge. SE cor. NE¼ NW¼ Sec. 9, T. 62 N., R. 20 W. (Wallace B. Howe, 1953).

Collinsville limestone (type locality for *Archaeolithophyllum delicatium*). Collinsville, Madison County, Illinois. Near center W½ SW¼, Sec. 34, T. 3 N., R. 8 W. (Wallace B. Howe, 1954).

SYSTEMATIC DESCRIPTIONS

Class RHODOPHYTA
Family CORALLINACEAE
Genus ARCHAEOLITHOPHYLLUM
Johnson, n. gen.

The plants developed small irregular platy or crustose masses which appear to have grown unattached on the sea bottom. Some are relatively flat; others curved and irregular. In some cases small protuberances or even branches developed on the upper surface.

The tissue of the thallus differentiates into a thick hypothallus possessing large polygonal cells and a thinner perithallus having much smaller rectangular cells. The sporangia are collected into conceptacles.

Type species.—*Archaeolithophyllum missouriensum*, n. sp.

ARCHAEOLITHOPHYLLUM MISSOURIENSUM
Johnson, n. sp.
Pl. 14, fig. 1–3, 5, 6

Description.—Thallus forms a small thin plate or irregular crustose mass from 0.5 to 1.8 mm. thick. Some are flat; others are curved and warped. In some cases, small protuberances or even slender branches developed on the upper surface. The tissue is well differentiated into a hypothallus and a perithallus. The hypothallus ranges in thickness from 400 to over 1100 μ and forms most of the tissue. It is coaxial, that is, formed of curved layers of very large cells. These are polygonal in outline, tending to be hexagonal in both transverse and longitudinal sections. The cells range greatly in size. Normally, the larger cells are in the center and the smaller at the margins. Cells measure 37 to 108 μ long and from 27 to 90 μ wide. In most specimens, the cells are arranged regularly in curved layers, but the cells do not form continuous rows perpendicular to the layers; on the contrary, they alternate in position so that the cells in alternate layers are in line.

The perithallus is relatively thin, approximately 150 to 180 μ thick, although in a few cases, a thickness of 700 μ is attained. It is composed of small rectangular cells which are arranged in regular layers. Commonly these are so arranged as to show a reticulate pattern in section. The cells measure 7 to 16 μ long and 7 to 14 μ wide, averaging about 12×9 μ.

Remains of highly arched conceptacles are present in several specimens. The conceptacle chambers measure 585 to 990 μ in diameter and 270 to 425 μ high. The highly arched top of the conceptacles suggests that they probably had a single large central aperture. One specimen (figure 6) seems to indicate this but does not show it clearly.

Remarks.—This form is the most common and most widespread species of the genus. It is represented by numerous specimens in the slides studied and occurs at all the localities listed above.

Type specimen.—U.S.G.S. fossil algae No. 324, from the Exline limestone, Carroll County, Missouri.

ARCHAEOLITHOPHYLLUM DELICATIUM
Johnson, n. sp.
Pl. 14, fig. 4

Description.—Thallus forms a crust about 200 μ thick, containing a coaxial hypothallus about 135 μ thick, with polygonal cells 14–36×14–22 μ. Perithallus thin, about 135 μ thick but thickening around the conceptacles. Perithallic cells rectangular 13–15 μ×8–10 μ, arranged in regular layers. Conceptacles highly arched, the best observed measured 468 μ in diameter and 391 μ high.

Remarks.—This species is not so large as *A. missouriensum* with smaller cells and smaller but more highly arched conceptacles.

Locality.—Collinsville limestone, Collinsville, Madison County, Illinois.

Type slide.—U.S.G.S. fossil algae No. 325.

CLASSIFICATION AND RELATIONSHIPS

Archaeolithophyllum has structural features characteristic of the family Corallinaceae and is to be considered a member of that family. It most closely resembles the Recent genus *Lithophyllum*, having similar hypothallus and perithallus and conceptacles of the same shape. It differs from *Lithophyllum* in the much greater size of the hypothallus and the shape and size of the cells of the hypothallic tissue.

The genus differs from the Solenoporacea by having well differentiated hypothallus and perithallus, in the shape of the hypothallic cells, the arrangement of cells in layers rather than rows, and probably by having conceptacles. Very few species of the Solenoporaceae have been observed with a noticeably differentiated hypothallus. None of them have a coaxial hypothallus. The cells of the Solenoporaceae are long and narrow and normally appear rectangular in longitudinal section, in contrast to the relatively wide polygonal cells of *Archaeolithophyllum*. Practically nothing is known concerning the reproductive organs of the Solenoporaceae so the well-defined conceptacles of *Archaeolitophyllum* are a very important feature separating the two.

MANUSCRIPT RECEIVED FEBRUARY 11, 1955

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 56–61, PL. 15, 1 TEXT-FIG., JANUARY 1956

OLENELLIDAE WITH ADVANCED CEPHALIC SPINES

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ABSTRACT—Eight species of Olenellidae (Trilobita) with advanced cephalic spines are discussed and an additional one described as new. They are distributed in four genera, three of which are proposed as new. These are *Fremontella*, n. gen. (genotype *Wanneria halli* Walcott), *Bristolia*, n. gen. (genotype *Mesonacis bristolensis*, Resser), and *Laudonia*, n. gen. (genotype *Laudonia bispinata*, n. sp.). In addition, the genus *Fremontia* Raw is redescribed.

INTRODUCTION

WALCOTT, in 1910, described several species of Olenellidae characterized by subanterior cephalic spines regarded as "advanced" genals. He, however, did not attach particular importance to the position of the genal spines and regarded the character as devoid of specific or varietal importance. Resser, in 1928, was of the opinion that the advanced genal spines have specific value and he proposed two species of "*Mesonacis*" differing almost exclusively in the location and shape of the spines. More recently Lochman, in 1952, regarded this feature as having only subspecific significance.

To the writer's knowledge only the following American species have been described characterized by advanced cephalic spines:

Fremontia fremonti (Walcott) Raw
Mesonacis bristolensis Resser
Mesonacis insolens Resser
Olenellus canadensis Walcott
Olenellus brevoculus Resser & Howell
Wanneria halli Walcott
Wanneria prima Lochman (= *Wanneria mexicana prima* Lochman)
Wanneria walcottana buelnaensis Lochman

In addition, Walcott referred a cephalon with very advanced cephalic spines to *Olenellus argentus* Walcott, a species characterized by "normal" genal spines. This reference cannot be accepted, as this cephalon (Walcott, 1910, p. 40, fig. 14). which has practically the same dimensions as the lectotype of *O. argentus* (here designated as specimen USNM 568 12d, illustrated in Walcott, 1910, p. 40, fig. 15), differs from it not only in the advanced genal spines but in the anterior border, less globose frontal glabellar lobe, longer and more posterior eye lobes and lack of metagenal spines.[1] This particular cephalon cannot be located at present and its proper identification must remain in abeyance.

The analysis of the eight species listed above leads the writer to conclude that the forward migration of the cephalic spines is a progressive, specialized and polyphyletic trend particularly characteristic of the subfamily Olenellinae though, as it will be presently seen, it is also known in the Wanneriinae.

Olenellus, though bearing "normal" genal spines, already displays this tendency. In some species, as *Olenellus schucherti* Resser & Howell (Resser & Howell, 1938, pl. 8, fig. 16) the posterior margin of the cephalon instead of being straight, breaks up in a broadly obtuse angle at the metagenal spine. In this species, the short portion of the posterior margin between the metagenal and the genal angle is directed obliquely outward and forward. However, this initial stage in the forward migration of the genal spines is so trivial that we would not be justified in calling them "advanced spines." In the genus *Fremontia*, on the other hand, the forward migration is already apparent. The metagenal angle, though still obtuse, is less so than in *O. schucherti* and the portion of the posterior margin between metagenal and genal angle is longer and directed less obliquely forward. Though the genal angle can still be recognized, the genal spines of *Fremontia* can be termed "advanced" when compared with those of a "normal" *Olenellus*. In other species, as in "*Mesonacis*"

[1] "Metagenal spines" is used here instead of "intergenal spines," a term which should be discarded as a confusing misnomer.

insolens Resser, the forward migration is so extreme that the genal angle cannot be recognized as such. In this and other species with very advanced genal spines what appears to be the genal angle is, in truth, the metagenal angle which has migrated outward and occupies the position originally held by the genal.

The location and shape of the advanced cephalic spines is clearly a character of specific importance, as already recognized by Resser. This is evident from the fact that no appreciable individual variation in the location and shape of the spines can be detected when several specimens of the same species are examined. The *presence* of advanced spines, on the other hand, when considered jointly with other cephalic features, seems to have true generic significance. Four genera, characterized by advanced cephalic spines, can be distinguished on the basis of glabellar, ocular and cephalic border features. Three of these genera are here described as new. For the sake of completeness the cephalic characters of the fourth genus, *Fremontia* Raw, will be added.

Acknowledgments.—It is a pleasure to state here the writer's indebtedness to Prof. Raymond C. Moore of the University of Kansas and to Dr. G. Arthur Cooper of the U. S. National Museum for the loan of Walcott's type specimens of *Wanneria halli* and of some other Olenellidae.

SYSTEMATIC DESCRIPTIONS

Family OLENELLIDAE Vogdes, 1893

Subfamily OLENELLINAE Vogdes, 1893

Genus FREMONTIA Raw, 1936

Pl. 15, fig. 6; Text-fig. 1B

Diagnosis.—Olenellidae with moderately advanced genal spines. Metagenal spines absent or minute in the adult. Metagenal angle broadly obtuse. Glabella parallel-sided, with three pairs of lateral glabellar lobes. Anterior (4p) lobes slightly narrower than the remainder, well defined by the second (3p) transglabellar furrow. Frontal lobe of glabella moderately expanded, reaching anterior border of cephalon. Eye lobes short, submedian (slightly posterior), reaching level of anterior third of preoccipital glabellar lobe. Cephalic border raised, narrowing anteriorly.

Type species.—*Olenellus fremonti* Walcott. Lectotype of species, here designated: USNM 56819a, illustrated in Walcott, 1910, pl. 37, fig. 2.

Described species referable to Fremontia.—

Olenellus canadensis Walcott
Olenellus brevoculus Resser & Howell
Wanneria walcottana buelnaensis Lochman

Remarks.—As Resser (1928, p. 6) pointed out, "a number of species are certainly included among Walcott's specimens grouped under *Olenellus fremonti*." In particular, the series of specimens illustrated in Walcott, 1910, pl. 37, fig. 8 to 19, showing the "progressive migration" of the genal spines in *Fremontia fremonti* belong not only to more than one species but also to more than a single genus. If we were to take Walcott's series at its face value and accept that the specimens represent successive growth stages of *F. fremonti*, we would be forced to admit that: (1) the genal spines migrated forward (fig. 8), (2) reached the anterolateral corners of the cephalon pointing straight outward (fig. 10), (3) after the next(?) molt they pointed outward and forward (fig. 9), (4) then began to migrate backward (fig. 11), (5) reached the "normal" position of genal spines (figs. 13 and 14), (6) then migrated forward again (fig. 17), (7) then backward again (fig. 18) and (8) then forward again (fig. 19)! Though such antics are not absolutely impossible, they are, to say the least, rather unlikely. That something is wrong with this interpretation must be apparent from the fact that the specimens illustrated by Walcott in fig. 10 and 12 are of exactly the same size.

Four of the specimens illustrated by Walcott have been located and the writer had the opportunity to examine them. USNM 56819n (Walcott's fig. 18, here reproduced in Pl. 15, fig. 6) seems to correspond to *Fremontia fremonti* but its poor preservation renders the identification somewhat uncertain. USNM 56819 (Walcott's fig. 16, here reproduced in Pl. 15, fig. 7) and 56819o (Walcott's fig. 19), certainly do not belong in this species or even genus. Their strongly constricted glabella, short eye lobes and well advanced genal spine suggest that they may represent a new species of the genus *Bristolia*, n. gen. (see below). USNM 56819g

(Walcott's fig. 11) is too poorly preserved for even a tentative generic identification. In this specimen the genal spines are directed obliquely backward and outward much as in the specimens of figs. 12 and 15 and not straight outward as shown in Walcott's sketch.

Olenellus canadensis Walcott, at least as illustrated by the lectotype (here designated: USNM 56814a, Walcott, 1910, pl. 38, fig. 1) seems referable to *Fremontia* even if the frontal lobe of the glabella is more expanded than in the genotype and the cephalic border is somewhat wider. In this species the reentrant angle at the base of the genal spine reaches the level of the mid-length of the preoccipital glabellar lobe, whereas in *F. fremonti* it reaches only to the level of the occipital furrow. The fragmentary cephala referred by Walcott to *O. canadensis* (1910, pl. 38, fig. 4, 5 and 7) obviously belong in a very different species. They are, however, too fragmentary for even generic identification.

Olenellus brevoculus Resser & Howell (Resser & Howell, 1938, p. 225, pl. 8, fig. 18 and 19) seems also referable to *Fremontia*. In this species the reentrant angle at the base of the genal spines reaches the level of the occipital furrow, much as in the genotype of *Fremontia*.

Wanneria walcottana buelnaensis Lochman (Lochman, 1952, p. 98, pl. 19, figs. 1–6) has all the cogent features of a true *Fremontia*. This form is clearly very different from *Wanneria walcottana* (Wanner) Walcott (Wanner, 1901, pl. 31, fig. 1; Walcott, 1910, pl. 30, fig. 1 and 2; Resser & Howell, 1938, pl. 10, fig. 8 and 9, pl. 11). It can be easily differentiated by its parallel sided glabella, very little expanded frontal glabellar lobe, narrow and raised cephalic border and small occipital node. In addition, the eye lobes are somewhat longer than in *W. walcottana*, as illustrated by the holotype (Wanner, 1901, pl. 31, fig. 1). These features, and the moderately advanced genal spines, are typical of *Fremontia*. In this species the genal spines are slightly more advanced than in *F. fremonti*, the re-entrant angle at the base of the spines reaching the level of the preoccipital glabellar furrow. *Fremontia buelnaensis* (Lochman) is distinguished from all other species by a peculiar row of pits along the border furrow in front of the genal spines. This is a unique feature, quite different from the row of pits carried by *Wanneria walcottana* along the free inner edge of the cephalic doublure (Wanner, 1901, p. 269, pl. 32, fig. 1 and 2), not observable on the dorsal surface of the cephalon.

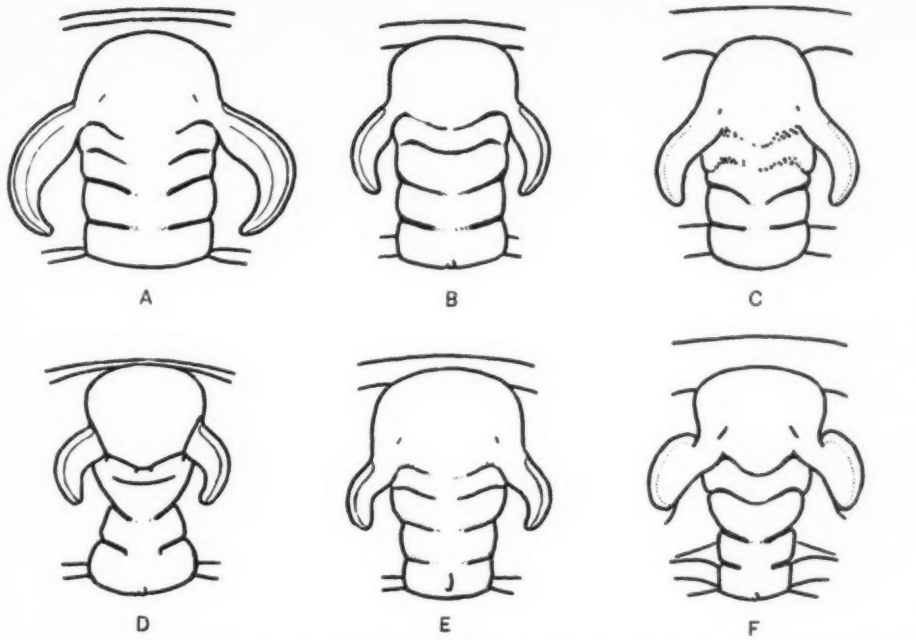
Genus FREMONTELLA, n. gen.
Pl. 15, fig. 1–3, 8–9; Text-fig. 1C

Diagnosis.—Olenellinae with well advanced genal spines. Metagenal spines absent in the adult. Metagenal angle subrectangular. Glabella parallel-sided with three pairs of lateral glabellar lobes, the anterior (4p) narrower than the remainder and ill-defined. Frontal glabellar lobe not expanded, evenly rounded anteriorly, slightly encroaching over anterior border of cephalon. Eye lobes short, posterior, reaching level of mid-length of preoccipital glabellar lobe. Cephalic border wide, slightly raised andlflat.

Type species.—*Wanneria halli* Walcott. Lectotype of species, here designated: USNM 56806c, illustrated in Walcott, 1910, pl. 31, fig. 3.

Remarks.—Pl. 15, fig. 1 and 2 are unretouched photographs of the lectotype. The three lateral glabellar lobes are plainly seen. In Walcott's original illustration of the same specimen the first (4p) lateral glabellar lobe is not observable. Pl. 15, fig. 3, 8 and 9 are photographs of the small cephala illustrated by Walcott, 1910, pl. 31, fig. 6, 4 and 2 respectively (USNM 56806f, 56806d and 56806b). USNM 56806f is 2.7 mm. long and not 1.0 mm. as would appear from Walcott's fig. 6.

Fremontella, n. gen., seems a true Olenellinae related to *Olenellus* and easily distinguished from *Wanneria* in the shape and segmentation of the glabella. *Fremontella halli* (Walcott) resembles *Olenellus wanneri* Resser & Howell (1938, p. 224, pl. 7, fig. 1) and *O. crassimarginatus* Walcott (Walcott, 1910, pl. 35, fig. 8; Resser & Howell, 1938, pl. 7, fig. 2) in the glabellar features, attachment of eye lobe to frontal glabellar lobe, and wide, flat cephalic border. The main differences are found in the short eye lobes and in the advanced genal spines the reëntrant angles of which reach the level of the second (3p) lateral glabellar furrow.



TEXT-FIG. 1—Cephalic axial region of A, *Olenellus thompsoni* (Hall) Billings, ×0.85. B, *Fremontia fremonti* (Walcott) Raw, ×1.35. C, *Fremontella halli* (Walcott), ×1.5. D, *Bristolia bristolensis* (Resser), ×1.5. E, *Wanneria walcottana* (Wanner) Walcott, ×0.85. F, *Laudonia bispinata* n. sp., ×3.3.

Genus BRISTOLIA, n. gen.
Pl. 15, fig. 7; Text-fig. 1D

Diagnosis.—Olenellinae with well advanced genal spines. Metagenal spines absent in adult. Metagenal angle narrowly obtuse to acute. Glabella with three pairs of lateral glabellar lobes, strongly constricted at the level of the preoccipital furrow. Second (3p) furrow transglabellar, gently curved backward, not reaching the axial furrows. Preoccipital (2p) furrow curved, chevron shaped, disconnected at middle. Frontal glabellar lobe pyriform, expanded in front and encroaching over anterior border of cephalon. Occipital ring broad (sag.) and as wide (tr.) as frontal glabellar lobe. Eye lobes short, submedian (slightly anterior), reaching level of preoccipital furrow. Cephalic border raised, narrowing anteriorly.

Type species.—*Mesonacis bristolensis* Resser. Lectotype of species, here designated: USNM 78390, illustrated in Resser, 1928, pl. 2, fig. 5–6.

Described species referable to Bristolia, n. gen.—*Mesonacis insolens* Resser.

Remarks.—*Bristolia*, n. gen., is easily distinguished from all other Olenelidae by the peculiar shape and segmentation of the glabella and by its short, slightly anterior eye lobes. *Bristolia insolens* (Resser) (Resser, 1928, p. 8, pl. 2, fig. 1–4 and 8) is very similar to the genotype differing, from it mostly in the location and shape of the genal spines. In *B. bristolensis* they follow the curvature of the cephalic margin and the re-entrant angle is located at the level of the second (3p) glabellar furrow while in *B. insolens* they curve frontward and then backward, the re-entrant angle being located at the level of the anterior third of the frontal glabellar lobe.

Bristolia, n. gen., can be safely placed in the Olenellinae as the thorax of *B. insolens* (Resser, 1928, pl. 2, fig. 1) shows the macropleural development of the third thoracic segment characteristic of the subfamily.

Subfamily WANNERIINAE Hupé, 1952
Genus LAUDONIA, n. gen.

Diagnosis.—Wanneriinae with well advanced genal spines. Metagenal spines well developed in adult. Metagenal angle slightly obtuse to slightly acute. Glabella with three pairs of lateral glabellar lobes and a pair of small depressions in front of the first lateral glabellar furrow. Glabella tapering backward. Frontal glabellar lobe expanded anteriorly, reaching the anterior border of cephalon. Eye lobes short, submedian (slightly posterior) reaching level of anterior third of second (3p) lateral glabellar lobe. Posterior genal ridge conspicuous. Cephalic border wide, slightly raised and flat.

Type species.—*Laudonia bispinata*, n. sp.

Described species referable to Laudonia *n. gen.*—*Wanneria prima* Lochman (= *Wanneria mexicana prima* Lochman).

LAUDONIA BISPINATA, n. sp.
Pl. 15, fig. 4, 5; Text-fig. 1F

Description.—Cephalon semielliptical in outline, 1.5 times wider than long. Glabella expanded anteriorly and tapering posteriorly, with three pairs of lateral glabellar lobes, the anterior one (4p) slightly narrower than the remainder. Frontal glabellar lobe expanded anteriorly, encroaching over anterior border of cephalon, and bearing a pair of slit-like depressions directed obliquely outward and backward near the postero-lateral corners. Lateral glabellar furrows reaching the axial furrows, chevron shaped and transglabellar but fainter at the middle. Those of the 3p pair somewhat less oblique than the remainder, becoming normal to the sagittal line in the vicinity of the axial furrows. Occipital furrow disconnected at the middle. Occipital ring as broad (sag.) and wide (tr.) as the preoccipital lobe, bearing a small median node near posterior edge.

Eye lobes short, reniform, slightly posterior, extending from the level of the posterior third of the frontal glabellar lobe to just behind the level of the second (3p) lateral glabellar furrow.

Posterior genal ridge raised, conspicuous, flaring near glabella into a triangular elevated area extending between posterior extremity of eye lobe and occipital furrow. Anterior edge of ridge vanishing at border furrow but posterior edge continuing faintly across cephalic border and becoming more visible along metagenal spine, running close to its adaxial edge.

Cephalic border wide, slightly raised over genal regions, flat, marked off by a wide and shallow furrow which becomes ill-defined between genal spines and anterolateral corners of glabella.

Metagenal spines conspicuous, simulating true genal spines, in direct continuation of curvature of lateral margin. Genal spines very anterior, broad and long, following the curvature of the anterior margin of the cephalon. Re-entrant angle at base of genal spines located at level of mid-length of frontal glabellar lobe.

Thorax and pygidum unknown.

Remarks.—*Laudonia*, n. gen., is easily distinguished from all other Olenellidae by the

EXPLANATION OF PLATE 15

FIG. *1–3, 8, 9*—*Fremontella halli* (Walcott) Harrington. *1*, Lectotype, USNM 56806c, (Walcott, 1910, pl. 31, fig. 3) ×1.6. *2*, Enlargement showing the glabella, ×2.3. *3*, Cephalon 2.7 mm. long, USNM 56806f (Walcott, 1910, pl. 31, fig. 6), ×6.6. *8*, Cephalon 3 mm. long, USNM 56806d (Walcott, 1910, pl. 31, fig. 4), ×8. *9*, Cephalon 5 mm. long, USNM 56806b (Walcott, 1910, pl. 31, fig. 2), ×5. All specimens from locality 56c, northeast of Helena, Shelby County, Alabama. Montevallo formation, Lower Cambrian. (p. 58)

4, 5—*Laudonia bispinata*, n. sp. *4*, Holotype, Kansas Univ. Coll. 9465T1, ×4.5. *5*, Enlargement showing the posterior genal ridge and the metagenal spine, ×5. Mumm Peak, Robson District, British Columbia. Mahato formation, Lower Cambrian. (p. 60)

6—*Fremontia fremonti* (Walcott) Raw. Specimen 15 mm. long, USNM 56819n (Walcott, 1910, pl. 37, fig. 18), ×2.2. Locality 52, Prospect Mountain, Eureka District, Nevada. Lower Cambrian. (p. 57)

7—*Bristolia* sp., Specimen 9 mm. long, USNM 56819 Walcott, 1910, pl. 37, fig. 16 as *Olenellus fremonti*), ×3.8. Locality 52, Prospect Mountain, Eureka District, Nevada. Lower Cambrian (p. 59)

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2

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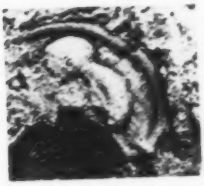

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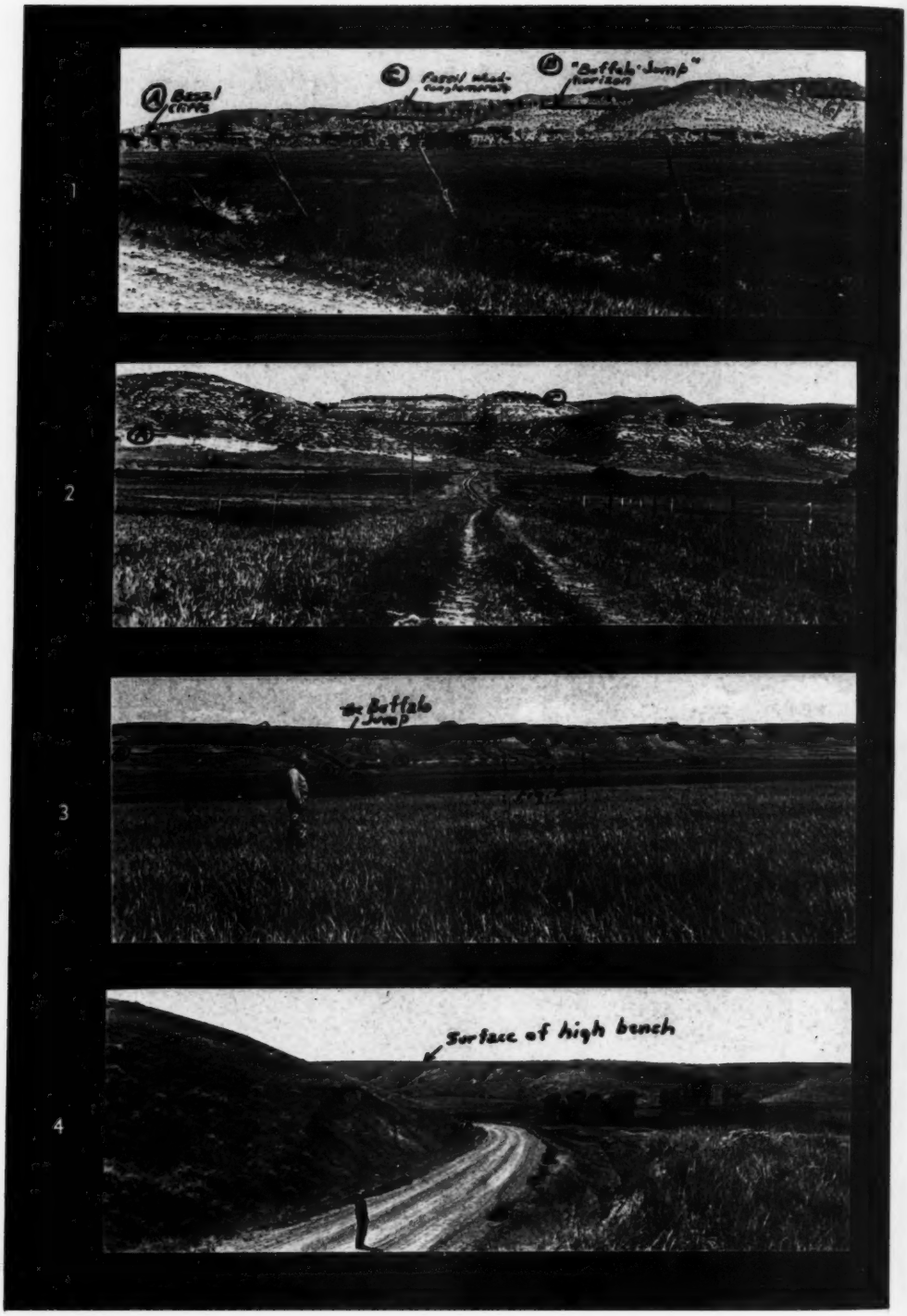

Dorr, Miocene mammals, Montana

presence of well advanced genal and metagenal spines, seems related to *Wanneria* Walcott and to *Esmeraldina* Resser & Howell. The shape and segmentation of the glabella of *L. bispinata* Harrington, n. sp., is closely comparable to that of *Wanneria occidens* Walcott (Walcott, 1913, pl. 53, fig. 2) placed in their genus *Esmeraldina* by Resser & Howell (1938, p. 229). The generic assignment of *W. occidens* to *Esmeraldina* is, however, rather questionable as the species seems more closely related to *Wanneria walcottana* that to the genotype of *Esmeraldina, E.* ("*Holmia*") *rowei* (Walcott) Resser & Howell (Walcott, 1910, pl. 29, fig. 1–11). The mere presence of a fairly long occipital spine in *W. occidens* is surely not enough to assign the species to *Esmeraldina*.

Laudonia bispinata Harrington, n. sp., is closely similar to the cephala described and illustrated by Lochman from northwestern Sonora, Mexico, as *Wanneria mexicana prima* Lochman (Lochman, 1952, p. 96, pl. 18, fig. 1–3). *Laudonia prima* (Lochman) differs from the genotype mainly in having somewhat longer eye lobes and in the less advanced genal spines, the re-entrant angle of which is located at the level of the second (3p) lateral glabellar furrow. Moreover, the metagenal angle is acute in *L. bispinata* and narrowly obtuse in *L. prima*.

Horizon and locality.—Mahto formation, Mumm Peak, Robson District, British Columbia. Coll: Dr. L. R. Laudon.

Holotype.—No. 945T1 University of Kansas Invert. Coll.

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MANUSCRIPT RECEIVED APRIL 1, 1955

EXPLANATION OF PLATE 16

FIG. *1*—Northern portion of bluffs on east side of Madison River valley in SE ¼, Sec. 4, T. 1 N. R. 2 E., Galatin Co., Mont. Type locality of Madison Valley formation. Cliffs only at base of bluffs. "Buffalo Jump" horizon not cliff-forming. Fossil wood-conglomerate horizon not cliff-forming although most marked lithologic change occurs at that level. Picture taken about 2 miles south of old cement plant. (p. 63)

2—Central portion of same bluffs. View east along south boundary of Sec. 34, T. 1 N. R. 2 E. Only upper part of basal cliff forming horizons of fig. 1 still exposed; disappearing below alluvium because of southward dip component. "Buffalo Jump" horizon strongly cliff-forming at right, more so to left (north) just out of picture (fig. 3, below). (p. 63)

3—Distant view eastward to central portion of bluffs from high bench on west side of Madison River valley. Area included in fig. 2 indicated by arrows. "Buffalo Jump" horizon clearly visible. Lower cliff-forming units (fig. 1) are brought up by fault. Fossil wood-conglomerate horizon indistinguishable. (p. 63)

4—Ash channel fill exposed in road cut. Type locality for *Hypsoparia bozemanensis* and *Perognathoides madisonensis*, and source of Anceney local fauna. View to west. (p. 65)

JOURNAL OF PALEONTOLOGY, VOL, 30, NO. 1, P. 62–74, PL. 16–18, 2 TEXT-FIG., JANUARY 1956

ANCENEY LOCAL MAMMAL FAUNA, LATEST MIOCENE, MADISON VALLEY FORMATION, MONTANA[1]

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ABSTRACT—The Madison Valley formation has its type locality in the eastern bluffs of the lower Madison River, south of Three Forks, Montana. A fluviatile deposit with rare lacustrine lenses, it overlies the Miocene *Leuciscus turneri* lake beds. Late Miocene mammals have been collected from the Madison Valley formation from exposures in the river bluffs, but the localities and stratigraphic levels from which many came remain uncertain or are inexactly recorded. New collections from a gray volcanic ash channel fill in the Madison Valley formation southeast of the type locality have yielded a faunule here named the Anceney local fauna. This faunule includes: *Mesogaulus?* cf. *M. ballensis*, *Monosaulax pansus?*, *Martes* sp., *Hypsoparia bozemanensis*, *Merychippus* (*Protohippus*) near *M. intermontanus*, and a camelid resembling *Rakomylus*. A new species of heteromyid rodent, described here as *Perognathoides madisonensis*, was also found, The fossil bearing horizon probably correlates with beds in the upper quarter of the type section.

INTRODUCTION

H. E. Wood, 2nd (1938, p. 291–292) called attention to an extensive section of Cenozoic continental deposits preserved in the vicinity of Three Forks, Montana, at the headwaters of the Missouri River, Gallatin County, Montana (Text-fig. 1). Included in that area are beds of early Oligocene, early through late Miocene, Pleistocene and possibly Pliocene age. Cenozoic strata are particularly well exposed in bluffs along both the eastern and western sides of the lower Madison River valley for about twelve miles south from Three Forks. These deposits were the subject of a series of publications by Douglass (1899, 1901a and b, 1903, 1907, 1908, 1909a and b) who made an extensive collection of fossil mammals from the exposures in the river bluffs.

In the bluffs along the western side of the valley are found coarse, fluviatile deposits termed the "John Day equivalent" by Wood who reported on remains of the early Miocene rhinoceros, *Diceratherium armatum* Marsh, collected from those deposits (Wood, H. E. 2nd, 1933). A gentle southeastward dip of about three degrees carries the "John Day equivalent" below the alluvium of the Madison River valley. On the eastern side of the valley, lacustrine deposits at the base of the northern end of the bluffs have been called the "*Leuciscus turneri*" beds by H. E. Wood, 2nd (1941, p. 24). These beds are stratigraphically higher and evidently younger than the "John Day equivalent"; possibly they are late Hemingfordian (late middle Miocene) or early Barstovian (early late Miocene) in age.

The remainder of the bluffs above are the type locality of the Madison Valley formation.

MADISON VALLEY FORMATION

In the past the Madison Valley formation (Douglass, 1907) has been variously called the Bozeman lake beds, Loup Fork, Madison Valley beds and Bozeman formation. It underlies and is locally exposed on the high bench that declines gently eastward from the top of the eastern bluffs to the Gallatin River valley. In general, the surface slope of this bench closely approximates the dip of the underlying strata.

The geographic distribution, geologic relationships and general stratigraphy of the formation have been discussed in the papers of Douglass cited above, and also at some length by Peale (1893, 1896), Iddings & Weed (1894) and Haynes (1916) as part of the "Bozeman lake beds" or "Bozeman formation."

[1] Abstract published December, 1954, in Geol. Soc. Am. Bull., vol. 65, p. 1245, under title: Very late Miocene (late Barstovian) mammal faunule from the Madison Valley formation, Montana.

Along the eastern side of the Madison River valley the lowest exposed beds of the Madison Valley formation are found at the northern end of the bluffs because of the southward dip component. Lensing, minor folding and local small scale faulting make it difficult to trace single stratigraphic units for any great distance along the face of the bluffs. The only really persistent rock unit is a coarse, usually poorly cemented conglomerate of subrounded to rounded, varicolored metaquartzitic and granitic material. This conglomerate caps the bluffs throughout much of their extent. A horizon in which silicified fossil wood is abundant occurs at or near the base of the conglomerate. Hereinafter this will be referred to as the "fossil wood-conglomerate" horizon.

In the course of this study, detailed stratigraphic sections were measured at the northern, middle and southern parts of the eastern bluffs. These indicate a composite total thickness of approximately 564 feet for the Madison Valley formation there. The lithology of the formation is roughly expressed by the following percentages:

Conglomerate	ca. 14%
Sandstone, conglomeratic to fine, often tuffaceous	ca. 64%
Siltstone, shale, claystone	ca. 15%
Ash, relatively pure	ca. 5%
Limestone and marl, fresh-water, small local lenses	ca. 2%

It has been suggested that the fossil mammals collected and reported largely by Douglass from the Madison Valley formation may represent faunas of two distinct ages; one Miocene, the other presumably Pliocene (Chardin & Stirton, 1934; p. 282, note to table 2; p. 285). H. E. Wood (1938) suggested that a lithologic change in degree of consolidation could be recognized that might correspond with the postulated faunal break. With this possibility in mind, the following observations were made in the field.

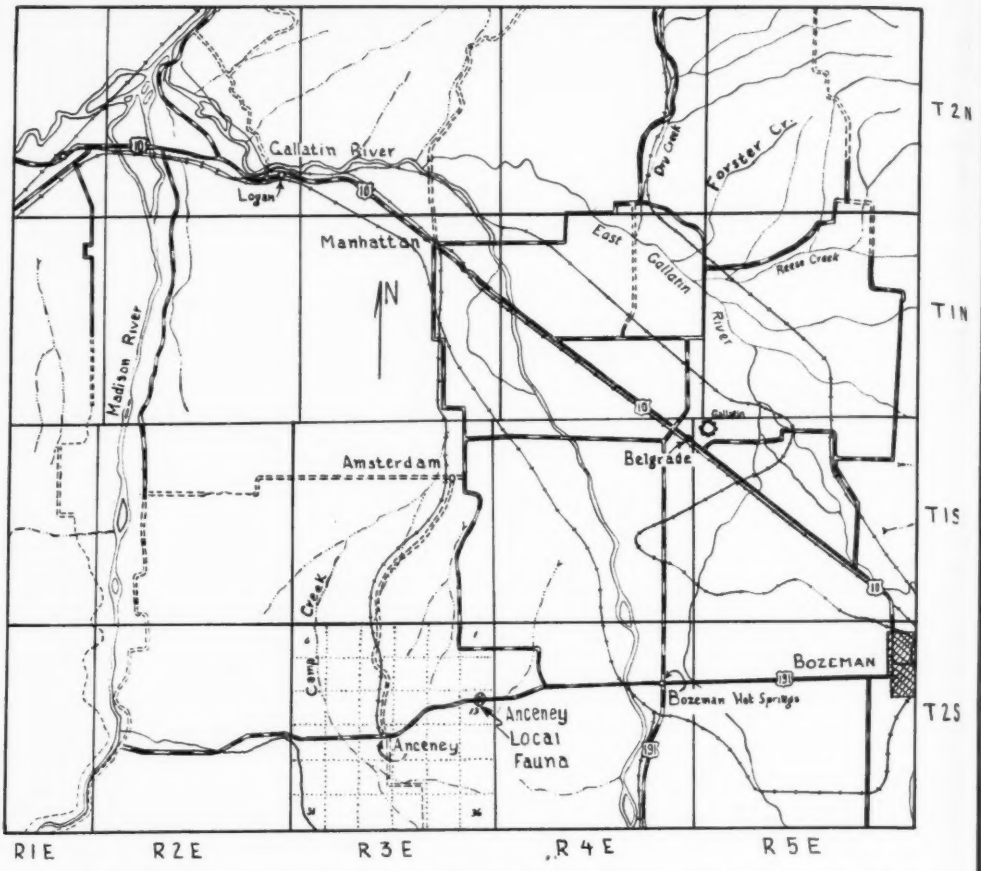
At the northern end of the bluffs the lower approximately 90 feet of strata are strongly cliff forming, whereas the remaining 250 feet above form gentle slopes frequently alternating with thin, resistant ledges (Pl. 16, fig. 1).

Farther south, in the central portion of the bluffs (Pl. 16, fig. 2, 3), the exposed

TEXT-FIG. 1.—Index map. General area of discussion outlined. Crossed-circle symbol for fossil locality. Reproduced from a portion of Raisz' map, "Landforms of the United States" to accompany Atwoods "Physiographic Provinces of North America," 6th Ed., 1954.

beds are, for the most part, equivalent to those that at the northern end form gentle slopes and minor ledges, yet here they are more conspicuously cliff forming up to the fossil wood-conglomerate horizon. One conspicuous and rather extensive cliff forming level here was used for generations by the Indians as a "buffalo jump," as evidenced by an accumulation of bison bones over ten feet thick that so enriches the soil at the cliff base as to cause a difference in vegetation visible for miles. This so-called "buffalo jump horizon," as shown on Pl. 16, fig. 1, 2, is locally strongly cliff forming in the central portion of the bluffs, but at the northern end is inconspicuous.

The beds exposed in the southern part of the bluffs are stratigraphically higher than those below the fossil wood-conglomerate



TEXT-FIG. 2.—Locality map for Anceney local fauna shown in center of N. ½, Sec. 13, T. 2 S. R. 3 E., Gallatin County, Montana.

horizon in the northern and central parts, but here again there are several rather conspicuous cliff forming horizons.

In all the beds below the fossil wood-conglomerate horizon, no single conspicuous change in the degree of consolidation was found that could be shown to consistently occur at the same stratigraphic level throughout the extent of the bluffs. Available evidence thus fails to support the suggestion that a change in degree of consolidation will serve as a lithologic criterion for recognition of the level of the proposed faunal discontinuity. In any case there is no longer any good a priori reason why such a coincidence of lithologic and faunal discontinuities should necessarily be expected at the Mio-Pliocene or any other epoch boundary. The most conspicuous and at the same time widespread lithologic change that can be recognized along the eastern river bluffs occurs at the base of the coarse conglomerate with the fossil wood horizon already mentioned. However, there is no marked change in degree of consolidation at that level. Moreover, the inadequacy of the horizon data accompanying the majority of the fossil mammal specimens from the bluffs makes it difficult or even impossible to determine whether they were collected from above or below that level. In some cases the specimens were found on the surface, possibly at some distance from the level of their origin. I have not seen suffi-

TABLE 1.—MEASUREMENTS (MM.) OF CM 8865 AND HOLOTYPE OF *Mesogaulus ballensis* RIGGS

	Posterior edge of incisive alveolus to posterior edge of M_1 alveolus	Length of lower molar series	Length of diastema	Antero-posterior diameter of P_4	Maximum transverse diameter of P_4	Depth of mandible below M_1 alveolus
M. ballensis Field Museum P5929. Measurements from Riggs, 1899	23.0	13.0	10.0	9.0	4.2	17.0 (Riggs) or 13.5*
CM 8865	ca. 20.5	ca. 11.9	10.0	8.5 at alveolus	3.8 at alveolus	13.8

* Measurements of a cast of the type and of the type figure suggest the lesser depth as perhaps more correct.

cient evidence as yet for postulating a coincidence of lithologic and faunal breaks at this or any other particular level within the Madison Valley formation, although conceivably such might later prove to be so.

ANCENEY LOCAL FAUNA

The possibility that specimens heretofore described from the Madison Valley formation may represent a mixture of two distinct faunas, and the fact that horizon and locality data for the specimens are poor, make significant the discovery in the Madison Valley formation of a small suite of undoubtedly associated fossil mammals. The fossils were found in a gray volcanic ash channel fill exposed in a cut along the south side of the road between the towns of Bozeman and Anceney. The locality lies on the divide between the Madison and Gallatin rivers, about 13 miles west of Bozeman, in the center of the N½, Sec. 13, T.2S.–R.3E., Gallatin County, Montana (Text-fig. 2; Pl. 16, fig. 4). Fossils were first discovered there in 1939 by a Carnegie Museum field party under the leadership of Dr. J. L. Kay, although some of the specimens were collected in subsequent years.

It is desirable to preserve the identity and clearly indicate the fact of association of the specimens from this locality; therefore, the faunule is here named the Anceney local fauna after the nearby town of Anceney.

Unfortunately, this locality lies several miles east of the nearest exposures in the Madison River valley bluffs. Lack of outcrops prevented determination of the exact stratigraphic relationship between beds at this locality and those at the type locality of the Madison Valley formation. However, lithologic similarity and the approximation of the surface of the bench to a dip slope suggest that the fossil horizon correlates with beds exposed in the upper part, probably the upper quarter, of the river bluffs.

SYSTEMATIC DESCRIPTIONS

Class MAMMALIA
Order RODENTIA
Family MYLAGAULIDAE
MESOGAULUS? cf. M. BALLENSIS
Riggs, 1899
Pl. 17, fig. 4, 5

Carnegie Museum specimen No. 8865 is the right ramus of a mylagaulid lacking the angle, condyle, coronoid process and cheek teeth, but with the incisor and the alveoli of the cheek teeth preserved. The incomplete nature of the specimen, particularly the lack of cheek teeth, makes specific identification impossible and generic identification uncertain. The measurements in Table 1 show that the specimen is only very slightly smaller than the holotype of *Mesogaulus ballensis* Riggs in all dimensions.

The strongly curved lower incisor has a flat anterior face thinly covered with enamel and is triangular in cross-section with the posterior apex somewhat rounded. There are alveoli for three cheek teeth. The homologies of these teeth are discussed in an earlier paper (Dorr, 1952). The anterior alveolus contained the large, anteroposteriorly elongate P_4. This tooth was widest posteriorly, and was double-rooted. The roots separate about three millimeters below the lip of the alveolus, therefore the individual had probably reached a rather advanced age. The single-rooted M_1 that occupied the center alveolus appears to have been anteroposteriorly compressed as in *M. ballensis*. The posterior portion of the rearmost alveolus is broken away but enough of the alveolus remains to show that M_2 was hypsodont, single-rooted, more rounded

than the tooth in front of it, and inclined forward at an angle of about forty-five degrees to the plane of the alveolar margins of the teeth ahead.

A strong masseteric ridge joins the lower anterior margin of the coronoid process below the posterior third of the premolar alveolus and continues downward and backward toward the angle of the jaw.

The lower dental formula was $_{1-0-1-2}$. This shows a greater reduction than in *Promylagaulus* McGrew and probably more than in *Mylagaulodon* Sinclair. P_4 is relatively smaller than in *Ceratogaulus* Matthew, *Mylagaulus* Cope, or *Epigaulus* Gidley. In all dimensions the specimen falls within the size range of the various species included in *Mesogaulus* Riggs (as redefined by Cook & Gregory, 1941, p. 551).

The specimen is larger than *Mesogaulus praecursor* Cook & Gregory, *M. paniensis* (Matthew) or *M. vetus* (Matthew), comparing closely in size to *M. proximus* (Douglass) and *M. ballensis*. M_1 was reduced and transverse as in *M. ballensis* and in contrast to the condition of that tooth in the other species mentioned above. The reduction of the molars seems to have progressed farther in this specimen than in *M. ballensis*. The exact stratigraphic position of the holotype of *M. ballensis* is not known other than that it probably came from the upper beds (Barstovian?) of the Deep River escarpments near White Sulphur Springs, Montana (Riggs, 1899, p. 181). According to Dr. J. L. Kay of Carnegie Museum (oral communication, 1952) the Miocene beds in the escarpments near White Sulphur Springs are probably stratigraphically higher than are the beds (Arikareean?) four miles southeast of Fort Logan, Montana, from which a hitherto unrecorded lower jaw (CM 9565) referable to *M. paniensis* was collected by Kay in 1938.

Although CM 8865 compares most closely with *M. ballensis*, it may represent a slightly more advanced, possibly late Barstovian, form.

Family CASTORIDAE

Genus MONOSAULAX Stirton, 1935

MONOSAULAX PANSUS? (Cope), 1874

Pl. 18, fig. 4–6

A beaver skull and right lower jaw, CM 8925, is referable to *Monosaulax* Stirton and probably to *M. pansus* (Cope). The badly crushed skull lacks the portion posterior to M^3, but includes right I–M^3 and left I–M^2. The lower jaw retains I–M_1. An isolated left incisor was associated in the matrix. P_4 are unworn; M^{1-3} are in an early stage of wear.

The convex-faced incisors are ungrooved. P_4 has a hypostriid extending to the base of the tooth and a shorter mesostriid; mesoflexid and hypoflexid are adjacent; the para- and metafossettids are not connected to the flexids. The parafossettid in unworn P_4 and worn M_1 is isolated. M_1 is smaller than P_4 and not as elongate. Unworn P^4 has a long hypostria and shorter parastria; incipient meso- and metafossettes are present. The upper molars have very short mesostriae and long hypostriae. Para- and metafossettes are present. The border of the mesofossette is still connected to the outer enamel band on M^{2-3} having only shortly before lost connection with the mesostria. In M^1 the mesofossette is still weakly connected with the mesostria. The upper teeth have one external flexus and stria; the lower teeth have one internal flexid and striid.

The above details are consistent with Stirton's diagnosis (1935, p. 416) of the genus *Monosaulax* and distinguish the specimen from other castorid genera.

CM 8925 is slightly smaller than *Monosaulax pansus* and larger than *M. curtis* (Matthew). In structural details of the teeth it is close to both. It lacks the small fossettid, posterior to the parafossettid on M_1 and anterior to the parafossettid on M_{2-3}, found in *M. hesperus* (Douglass) (Stirton, 1935, p. 422). In *M. complexus* (Douglass) there are two anterior fossettes on M^1, and the parafossettid, in early stages, opens into the mesoflexid instead of to the outside (Stirton, 1935, p. 421). *M. senrudi* H. E. Wood is about twice as large as the Carnegie specimen, has striated incisors and a twinned metafossettid.

M. pansus has been reported from the Virgin Valley formation of Nevada that may be as old as late middle Miocene (late Hemingfordian); and from the latest Miocene (late Barstovian) or early Pliocene Lower Snake Creek beds of Nebraska; but is most commonly found in beds of middle and late Barstovian age.

TABLE 2.—MEASUREMENTS (MM.) OF *Monosaulax pansus?*, CM 8925
(Right dentition. At triturating surface except as shown.)

	P^4 at alveolus	M^1	M^2	M^3	P^4–M^3	Upper diastema	P_4 at alveolus	M_1	P_4–M_1 at alveolus	Lower diastema
Max. Ant.-Post. diam.	4.1	3.1	2.8	2.5	12.7 at alv.	ca. 15.0	3.3	3.3	7.7	ca. 10.0
Max. trans. diam.	4.3	3.4	3.2	3.0			4.0	3.1		

Family HETEROMYIDAE
Genus PEROGNATHOIDES A. E. Wood, 1935

Perognathoides WOOD, A. E., 1935, Carnegie Mus. Annals, vol. 24, p. 92–93.

PEROGNATHOIDES MADISONENSIS , n. sp.
Pl. 17, fig. 6, 7

Holotype.—No. 8770, Carnegie Museum of Pittsburgh Section of Vertebrate Paleontology. Partial right ramus of lower jaw, with incisor (lacking tip), and P_4–M_2 complete. Coronoid and angular processes lacking. Collected by author as a member of a Carnegie Museum field party, July, 1952.

Horizon and type locality.—Uppermost Miocene, Anceney local fauna, Madison Valley formation. From a gray volcanic ash channel fill exposed in a road cut along the south side of the road between Bozeman and Anceney, Montana, about thirteen miles west of Bozeman on the divide between the Madison and Gallatin rivers, Center of N.½, Sec. 13, T.2S.–R.3E., Gallatin County, Montana (text-fig. 2; pl. 1, fig. 4).

Diagnosis.—Smallest cheek tooth battery of any species of the genus so far described. Cheek teeth relatively high crowned. P_4 and M_2 about equal in size; M_1 only slightly larger.

P_4 quadricuspidate; nearly square in early wear stages. Anterior lophid may narrow slightly with additional wear; clearly bicuspidate with a distinct anterior reëntrant angle. No anteroconid in holotype.

M_{1-2} with enamel complete nearly to roots. Labial valley shallower than lingual valley; in M_1 partially closed by external cingulum at labial end. Lingual valley shal low, not extending to base of crown. H pattern present in early wear stages.

M_3 lacking in holotype.

Mental foramen anterior to middle of diastema.

Description and discussion of holotype.—Although much smaller, the holotype of *P. madisonensis* closely resembles in its enamel pattern and structure a specimen (Univ. California No. 28541) originally mentioned and figured by Hall (1930, p. 315–16), and later referred by A. E. Wood (1936, p. 116) to *P. halli* A. E. Wood. Hall figured P_4–M_1. By the time the specimen came into Wood's hands P_4 had been lost. Hall's figure leaves much to be desired, but appears to show P_4 lacking an anterior reentrant angle on the anterior lophid. This is in contrast to the condition in *P. madisonensis*. However, the enamel patterns on M_1 in the two specimens are nearly identical, the principal difference, other than size, lying in the shallower lingual valley extending only about half way down the crown in the holotype of *P. madisonensis*. M_{1-2}, with added wear, would posses a distinct H-pattern. A low cingular ridge joins the two lophids of M_1 across the labial end of the labial valley thus forming a low "dam" and completing the enclosure of a shallow depression between the labial halves of the lophids, a condition described by A. E. Wood (1936, p. 116) as occurring in the specimen he referred to *P. halli*. M_2 in *P. madisonensis* fails to show this character. The holotype lacks M_3 whose characters are therefore unknown. P_4–M_2 are high-crowned, but were revealed by dissection to

TABLE 3.—MEASUREMENTS (MM.) OF HOLOTYPE OF *Perognathoides madisonensis*, N. SP., CM 8770

	Diastema	Posterior edge of incisive alveolus to posterior edge of M_3	P_4–M_2	P_4	M_1	M_2
Antero-posterior	2.40	5.40	2.80	.90	.95	.85
Transverse				.90	1.15	1.10

possess distinct roots.

The fragmentary condition of the holotype makes it impossible to determine the nature of the jaw behind M_3.

The masseteric crest extends foward to a point about two thirds of the distance from P_4 to the posterior edge of the mental foramen and terminates slightly above the level of the upper edge of that foramen. There is no free, knob-like process at the anterior end of the masseteric crest.

The holotype of *P. madisonensis* is markedly smaller than that of any previously described species of the genus, being about 9% smaller than *P. cuyamensis* A. E. Wood, 1937.

The holotype of *P. madisonensis* differs structurally from *P. cuyamensis* by the absence of an anteroconid on P_4 and the distinctly bicuspid pattern of the anterior lophid of that tooth; from *P. quartus* (Hall, 1930a) in that P_4 is quadrangular and smaller than M_{1-2}, and by a greater degree of hypsodonty; from *P. tertius* (Hall, 1930a) by the relatively short, broad, quadrate P_4, and the subequal widths of M_{1-2}. *P. madisonensis* appears to have advanced slightly beyond the structural level of *P. halli* from the Barstow formation of California, but may be little if any younger.

Order CARNIVORA
Family MUSTELIDAE
Subfamily MUSTELINAE
Genus MARTES Frisch, 1775, sp. indet.
Pl. 17, fig. 1–3

A right lower jaw, CM 8864, preserving well worn P_2–M_1 and the alveoli of the canine, P_1 and M_2, is referred to the genus *Martes*. The specimen compares very closely with *Martes americana* Turton in details of construction but is perhaps smaller than is usual for that species.

The lower dental formula was ?–1–3–3. The lower premolars are trenchant, with very weak cingula. P_2 lacks the anterior and posterior cingular shelves but these are present on the other premolars. The premolar heels are narrow and rounded. P_4 has a small posterior accessory cuspule in line with the main cusp. The premolars are slightly less crowded, a little less massive, and relatively shorter than in *M. americana*. M_1 is almost identical with that tooth in *M. americana* except for the somewhat narrower, more rounded heel. The metaconid is similar in size and position. M_2 is missing in the specimen, but the alveolus is longer than wide. The fusion of the roots of that tooth has not progressed as far as

EXPLANATION OF PLATE 17

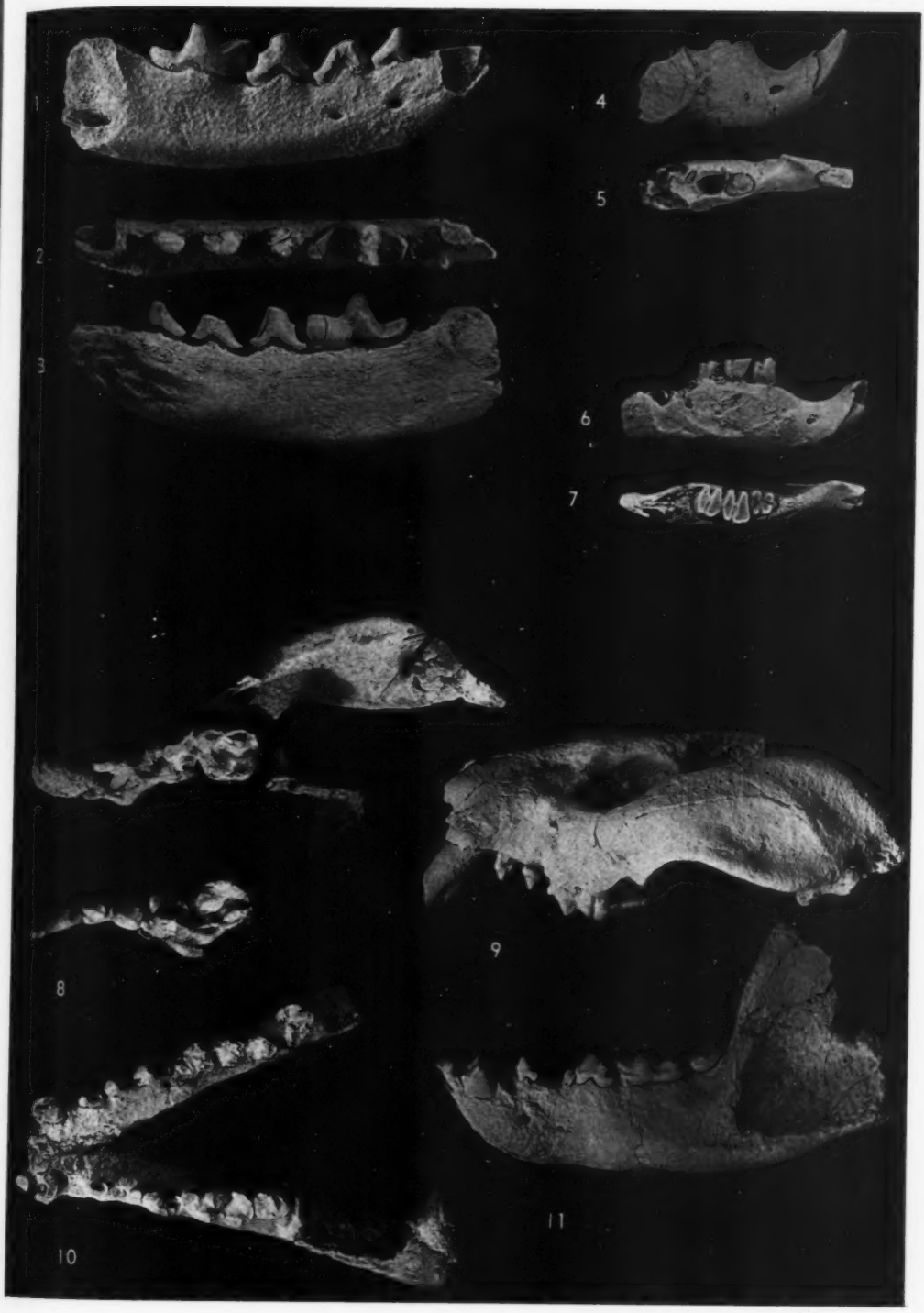
All specimens from Anceny local fauna, Madison Valley formation, Montana. Carnegie Museum of Pittsburgh, Section of Vertebrate Paleontology catalogue numbers given.

FIG. *1–3*—*Martes* sp. indet. Right lower jaw with P_2–M_1. Labial, occlusal and lingual views. CM 8864. ca. ×2. (p. 68)

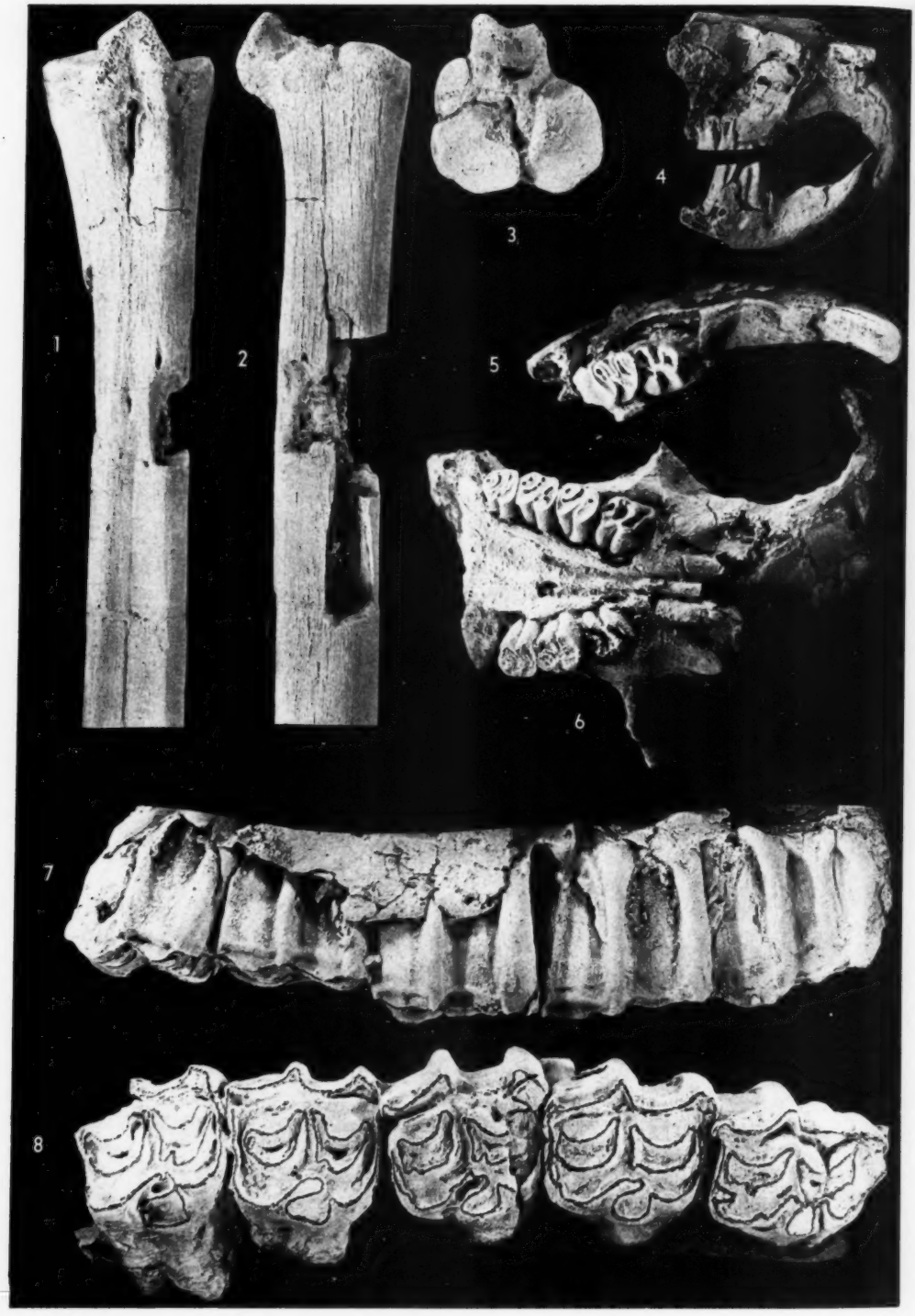
4, 5—*Mesogaulus* cf. *M. ballensis*. Right lower jaw. Labial and occlusal views. Anterior root of P_4 outlined. CM 8865. ca. ×1. (p. 65)

6, 7—*Perognathoides madisonensis*, n. sp. Holotype. Right lower jaw with P_4–M_2. Labial and occlusal views. CM 8770. ca. ×4. (p. 67)

8–11—*Hypsoparia bozemanensis* Dorr, 1954. Holotype. CM 9574. ca. ×1. *8, 9*, Skull, occlusal and lateral views. *10, 11*, Lower jaws, occlusal and lateral views. (p. 69)



Dorr, Miocene mammals, Montana



Dorr, Miocene mammals, Montana

TABLE 4.—MEASUREMENTS (MM.) OF RIGHT LOWER JAW OF *Martes* SP. INDET., CM 8864

	P_2–M_2	P_1 alveolus	P_2	P_3	P_4	M_1
Antero-posterior	18.5	1.5	2.95	4.0	4.6	7.3
Transverse	—	1.25	1.5	1.7	2.1	3.2

Posterior edge of incisive alveolus to posterior edge of M_2 alveolus—23.0. Depth of jaw below center edge of M_1 alveolus, labial side—7.9.

in *M. americana* because the middle of the alveolus is constricted from both sides by inward projecting ribs, indicating the presence of more nearly separate anterior and posterior roots. In specimens of *M. americana* examined, only one side of the M_2 alveolus was indented.

Although there is some doubt that pre-Pleistocene records of Recent mammal genera are to be trusted (Simpson, 1945, p. 113, footnote 2), particularly when based upon an identification of the lower jaw of a carnivore, nevertheless there appears to be no valid basis at present for distinguishing this specimen from *Martes* or for describing a new genus. *Martes* has been reported elsewhere from beds at least as old as late Miocene, Viret (1951, p. 53–60) alone recording five species of that genus from La Grive Saint-Alban, department of Isères, France.

Gidley (1927) described *Martes kinseyi* from "near Belgrade, Montana." The exact locality of the type of that species could not be ascertained, but the town of Belgrade is only 10 miles northeast of the locality at which the specimens described in this paper were collected, and *M. kinseyi* could have been found at about the same stratigraphic level in the Madison Valley formation. The type of *M. kinseyi*, however, is a much larger jaw than CM 8864. Size difference alone may not be sufficient evidence for distinguishing the two jaws because in the living species of *Martes* the size difference between sexes is greater than normal for carnivores. However, CM 8864 is not as relatively deep posteriorly as the lower jaws of *M. kinseyi*. P_{3-4} are shorter, less robust, and have narrower heels than in *M. kinseyi*.

It seems improbable that this specimen is older than late Miocene, but little reliance should be placed upon its age significance.

Subfamily LEPTARCTINAE
Genus HYPSOPARIA Dorr, 1954
HYPSOPARIA BOZEMANENSIS Dorr, 1954
Pl. 17, fig. 8–11

The genotype, *Hypsoparia bozemanensis*, was based upon the holotype, CM 9574, a remarkable partial skull and jaws, collected in association with one another and with the other members of the Anceney local fauna listed in this paper. The specimen was described at length and figured in an earlier paper when it was uncertain that the present study would be completed.

As mentioned in the original description, the most striking and distinctive structural feature of this genus is the extreme depth

EXPLANATION OF PLATE 18

All specimens from Anceney local fauna, Madison Valley formation, Montana. Carnegie Museum of Pittsburgh, Section of Vertebrate Paleontology catalogue numbers given.

FIG. *1–3*—Camel, gen. and sp. indet. Proximal portion of an incomplete left metatarsal. Distal end lacking. Specimen terminates in a ragged break just below the point shown at the lower margins of fig. 1 and 2. CM 8861. ca. ×1. (p. 71)

4–6—*Monosaulax pansus?*. CM 8925. *4*, Right side of skull and jaws, ca. ×1. *5*, Occlusal view, right lower jaw with incisor and P_4–M_1, ca. ×2. *6*, Palatal view of skull with right incisor, right P^4–M^2, and left P^4–M^2. ca. ×2. (p. 66)

7, 8—*Merychippus* (*Protohippus*) cf. *M.* (*P.*) *intermontanus*. Right P^2–M^2. Labial and occlusal views. Part of CM 8863, ca. ×1. (p. 70)

and specialization of the zygomatic arch and masseteric fossa. In these respects it is more advanced (but not necessarily younger) than the neotypes (Matthew, 1924) of *Leptarctus primus* Leidy, 1856, a genus and species occurring in the Bijou Hills local fauna (middle and late Barstovian) of South Dakota and the lower Snake Creek beds (late Barstovian and/or early Clarendonian) of Nebraska. In dental characters, however, it seems little if any more specialized or less primitive than *L. primus*.

Detailed comparisons with other known genera and species of leptarctines are unsatisfactory because of the fragmentary nature of most of the specimens and especially because of the general lack of preservation of the zygoma. In tooth structure alone, *H. bozemanensis* seems to be less primitive than *Mephititaxus* White, 1941 (middle Miocene, Hawthorne formation, Florida); less advanced than *Leptarctus wortmani* Matthew, 1924, (Valentine formation, Nebraska) in characters of P_3; and less advanced than *L. progressus* Simpson, 1930, (middle Pliocene, Florida), *L. oregonensis* Stock, 1930, (late Miocene, Oregon), and *Craterogale* Gazin, 1936, (latest Miocene or early Pliocene, Nebraska). The phylogeny of leptarctines is as yet poorly known; therefore, the weight of available evidence can only suggest that *H. bozemanensis* is of late Miocene rather than early Pliocene age.

Order PERISSODACTYLA
Family EQUIDAE
Genus MERYCHIPPUS Leidy, 1856
Subgenus PROTOHIPPUS Leidy, 1858

Protohippus LEIDY, 1858, Acad. Nat. Sci. Phila., Proc., 1858, p. 26. New genus.
Merychippus (*Protohippus*) Leidy, STIRTON, 1940, Univ. Calif. Pub., Dept. Geol. Sci. Bull., vol. 25, p. 165–198. *Protohippus* a subgenus of *Merychippus*.

MERYCHIPPUS (PROTOHIPPUS) near M. (P.) INTERMONTANUS Merriam, 1915
Pl. 18, fig. 7, 8

Two specimens collected by Dr. J. L. Kay in 1939 are referred to this genus and represent a rather advanced form of the subgenus. CM 8862 consists of a badly crushed palate including P^{2-3}, dP^4, and M^{1-3} on the right, and P^3, dP^4 and M^{1-2} on the left; also two indeterminate deciduous teeth, a fragment of a lower molar, and two cranial fragments. The permanent premolars had not completed their growth. M^{1-2} had completed growth and M^1 was just coming into wear so measurement of maximum crown height is possible on those two teeth. Right M^3 is represented by the enamel skeleton only and lacks cement. Right M^{1-2} were excavated and sectioned to display the enamel pattern to better advantage.

CM 8863 consists of a partial plate with right P^2–M^2 and left P^2. Associated with this were a right scapula, five fragmentary vertebrae, and parts of eight ribs. With due allowance for stage of wear, the teeth in this specimen and CM 8862 are alike in size, tooth proportions, curvature, and enamel pattern.

DP^4 in CM 8862 shows cementum on its base, has a simple pattern, but is too worn to show clearly the original characters of the enamel. The crochet and protoconule are nearly united, being slightly more widely separated on the right tooth. The hypoconal groove persists nearly to the base of the tooth.

In the permanent teeth the enamel pattern is simple. The fossette borders are uncomplicated. The protocone is rounded, connected to the protoselene at an early stage of wear, and separated from the hypocone nearly to the base of the enamel. The pli caballin and pli protoconule folds are present on P^3–M^2 (M^3 is either broken out or not fully formed in the specimens). The crochet is united to the protoconule in all but P^2, where they are slightly separated. In CM 8862, the hypoconal groove extends to within eight millimeters of the base of M^1 and to within eleven millimeters of the base in M^2. The teeth are longer than wide in early stages of wear but change to become wider than long with age. In CM 8862, M^{1-2} were fully formed with roots starting to close, but with unworn mesostyles, so a reliable measurement of the degree of hypsodonty is possible.

Neither of the specimens is sufficiently complete to show the very important facial features or foramina. The nature of the specimens does not encourage specific identification, but the teeth compare closely with those of *Merychippus* (*Protohippus*)

TABLE 5.—MEASUREMENTS (MM.) OF TWO SPECIMENS OF *Merychippus* (*Protohippus*) NEAR *M.* (*P.*) *intermontanus* MERRIAM

	CM 8862	CM 8863
Individual age	Advanced youth	Middle age
P^2–M^3		120.3
M^{1-3}	ca. 67.0	
dP^4		
A-P	23.3	
Tr	21.8	
Greatest diameter about 13 mm. above internal enamel base		
P^2 A-P		28.0
Tr		20.0
P^3 A-P		25.5
Tr		23.9
P^4 A-P		23.0
Tr		23.5
M^1 A-P	22.6	22.0
Tr	24.8	23.5
M^2 A-P	22.5	21.6
Tr	23.7	21.5
Maximum external crown height at mesostyle on unworn teeth		
M^1	36.2	
M^2	36.0	
Maximum internal crown height on unworn teeth at protocone		
M^1	18.1	
M^2	22.5	
Radius of curvature in millimeters		
P^4		35
M^1	35	
M^2	35	

campestris Gidley from the late Barstovian or early Clarendonian Pawnee Creek beds of Colorado, and *M.* (*P.*) *intermontanus* Merriam from the Barstow formation of California, in size, enamel pattern, degree of hypsodonty and radius of curvature. They differ from the former principally in retaining the hypoconal groove until a later stage of wear and in their somewhat higher crowns. They are somewhat lower crowned and have a slightly larger radius of curvature than *M. intermontanus*. Crown dimension ratios alter with age so are difficult to compare.

The specimens appear to be intermediate between the two species mentioned, but closest to the late Barstovian *M. intermontanus* in their relationship.

Order ARTIODACTYLA
Family CAMELIDAE
Camel, gen. and sp. indet.
Pl. 18, fig. 1–3

Carnegie Museum specimen 8861 is the left metatarsal, lacking the distal end, of a small camel. If the estimated length is approximately correct, the complete bone would have been only about 13 millimeters longer than the metatarsal of the holotype (CM 1610) of *Stenomylus gracilis* Peterson. However, it is relatively stouter, has a shallower, less pronounced posterior groove, and the anteroposterior dimensions of the proximal articular surface and shaft are relatively greater than in that species. Fusion of the metatarsals is complete throughout as much of the proximal end of the bone

as is preserved; more so, apparently, than in *S. gracilis*. The specimen is too incomplete for even subfamilial identification, but may have belonged to either a protolabine or stenomyline form. *Rakomylus* Frick, from the Santa Fe formation of New Mexico, seems to be the most nearly comparable camel in size, proportions, and age so far described.

TABLE 6.—MEASUREMENTS (MM.) OF CAMEL, GEN. AND SP. INDET., METATARSAL, CM 8861

Estimated original length	ca. 210.0
Actual length not including plantar process	148.0
Anteroposterior diameter of proximal end, including plantar process	25.5
Transverse diameter of proximal end	25.0
Anteroposterior diameter of shaft 80 mm. from proximal end	15.0
Transverse diameter of shaft 80 mm. from proximal end	14.5

AGE AND SIGNIFICANCE OF FAUNA

In what seems to be his final opinion, Douglass (1909a, in title) considered the mammal fauna of the Madison Valley formation to be late Miocene in age and nearly, though not exactly, contemporaneous with the Deep River (Montana), Flint Creek (Montana), Pawnee Creek (Colorado), Mascall (Oregon), and Santa Fe (New Mexico) faunas.

Simpson (1933, p. 102) considered the fauna to be of latest Miocene, about lower Santa Fe, age.

Chardin & Stirton (1934, p. 282, note to table 2; p. 285) suggested that the Madison Valley "fauna" might represent two distinct faunas, one Miocene, the other Pliocene in age.

H. E. Wood, 2nd., et al. (1941, pl. 1), on a chart show the Madison Valley formation as spanning a time interval definitely including the latter half of the Barstovian (late Miocene) age and questionably the initial half of the Clarendonian (early Pliocene) age, thus concurring with Chardin & Stirton.

As stated earlier, the Madison Valley fauna is undoubtedly a mixed assemblage from various levels within the formation and the horizon and locality data are such that there is little hope of accurately relocating the original place of occurrence of most of the specimens. Therefore, the Anceney local fauna is significant, representing as it does an assemblage from a single locality and horizon. The locality lies on the back slope of the bench between the Madison and Gallatin rivers, between ten and fifteen miles east and southeast of the type locality of the Madison Valley formation of Douglass; that is the bluffs bounding the Madison River valley on the east. The exact stratigraphic level of the faunule within the Madison Valley formation could not be determined by lithologic continuity. However, lithologic similarity, and the approximation of the surface of the bench to a dip slope, indicate that the fossil horizon correlates with beds exposed in the upper part, probably the upper quarter, of the river bluffs at the type locality.

The age significance of the individual faunal elements, discussed in the systematic descriptions, may be summarized as follows:

a. *Mesogaulus?* cf. *M. ballensis*—Holotype of species is Barstovian. Anceney specimen slightly more advanced, perhaps late Barstovian.

b. *Monosaulax pansus?*—Known range of species is late Hemingfordian to late Barstovian or possibly early Clarendonian. Most commonly middle and late Barstovian.

c. *Perognathoides madisonensis*—Species new in this faunule. Closest to, but perhaps slightly more advanced than *P. halli* (Barstow formation). Species probably late Barstovian, but possibly early Clarendonian judging from its structural level.

d. *Martes* sp. indet.—Genus reported from late Miocene to Recent. Significance uncertain.

e. *Hypsoparia bozemanensis*—Genus and species new in this faunule. Structural level suggests Barstovian, but possibly early Clarendonian age.

f. *Merychippus* (*Protohippus*) near *M.* (*P.*) *intermontanus*—A middle and late Barstovian species so far as known.

g. Camel, gen. and sp. indet.—Near *Rakomylus*. Late Barstovian or early Clarendonian.

The faunule evidently falls close to the Miocene-Pliocene boundary, but it seems best to consider it as late Barstovian (latest Miocene) in age.

The age and approximate stratigraphic position of the Anceney local fauna, in turn, suggest that most if not all of the Madison Valley formation is Miocene rather than early Pliocene in age. There has, as yet, been no satisfactory demonstration of mutually coincident faunal, lithologic and epoch boundaries within that formation.

ACKNOWLEDGMENTS

All of the field work and much of the laboratory work for this study was done while I was a member of the staff of the Carnegie Museum of Pittsburgh, Pennsylvania. Dr. J. LeRoy Kay, Curator of Vertebrate Fossils at Carnegie Museum, collected all but one of the specimens described here, collaborated in the field study of stratigraphy, offered much invaluable advice drawn from many years of experience in the area discussed, and kindly loaned the specimens to me that the study might be completed. This paper owes its existence in large part to his efforts.

The staff of the American Museum of Natural History, New York, made it possible to examine pertinent specimens in their paleontological collections.

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CEPHALOPODS FROM THE CANADIAN OF MARYLAND

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ABSTRACT—Cephalopods from the Canadian of Washington County, Maryland, include three members of the Ellesmeroceratidae from the lower Canadian Stonehenge formation, and from higher beds, an unnamed *Clelandoceras*. Higher Canadian strata have yielded a few fragments apparently of the Baltoceratidae, and a large number of isolated silicified endoceroid siphuncles. On the basis of this material seventeen new species are named, belonging to twelve genera, of which seven are new; one new subgenus is proposed. The new forms described are: *Ellesmeroceras* (*Metaellesmeroceras*), n. subgen., *E.* (*M.*) *anomalum*, *Oneotoceras? marylandicum*, *Phragmosiphon*, *P. septiferum*, *Stenosiphon*, *S. sandoi*, *Platysiphon*, *P. expansum* (genotype), *P. gracile*, *Escharendoceras*, *E. eccentricum* (genotype), *E. simplex*, *Mysticoceras fusiforme*, *Clitendoceras anomalum*, *C. subgracile*, *Retroclitendoeras*, *R. depressum*, *Pliendoceras*, *P. concavum*, *Lobosiphon*, *L. inexpectans*, *Mcqueenoceras cariniferum*, *M. ventrale*, *Coreanoceras lunatum*. *Proterocameroceras normale*. Present observations indicate that the Canadian endoceroids were highly diversified, in particular, in the features of the endosiphuncle, and that they have considerable faunal and stratigraphic significance.

INTRODUCTION

THE cephalopods described below were submitted for study by Dr. William E. Sando, who collected them in connection with a comprehensive study of the faunas and stratigraphy of the Canadian strata of Washington County, Maryland. The lower Canadian part of the section has yielded recognizable Ellesmeroceratidae, a family which is almost completely confined to that part of the column. The higher beds have yielded one fragmentary member of the Baltoceratidae, and the highest fossil horizon has yielded abundant if fragmentary specimens of the genus *Clelandoceras*, formerly known only from the Smithville formation of Arkansas.

The greater part of the collection consisted of isolated silicified endoceroid siphuncles. Though nondescript externally, they exhibited great variety in the organization of the endosiphuncle and in particular, of the form of the endosiphocone. As noted elsewhere (Flower, 1955) the endoceroids present rather special problems in taxonomy. Some weird paradoxes exist because some genera are based on gross shell features, some on early stages, some on the organization of the endosiphuncle, and the correlation of these generic groups is a matter largely but not completely clarified. Anomalously, the genera previously established in the Canadian of North America (Ulrich, Foerste, Miller & Unklesbay, 1944) have been based upon features of form, section, sutures, and no attention was given to the nature of the siphuncle wall, and little to the organization of the endosiphuncle. Yet it has long been evident from the investigations of Holm (1885) Ruedemann (1905, 1906) and Kobayashi (1931, 1934, 1935), that the features of the endosiphuncles supply valuable criteria of great potential taxonomic value. The present study was undertaken at a time when even richer and larger cephalopod faunas from New Mexico and western Texas, in which the endoceroids are most commonly represented by similar isolated siphuncles, was being prepared for study. It proved to be a matter of singular interest to find that the endosiphuncles supply valuable criteria for the recognition of genera and species, and are, in fact, sufficient in themselves for such purposes, and further, that quite a number of the genera here described as new are present in both regions. Further, the genera promise to have considerable significance in faunal and stratigraphic correlation. The present study required first a reexamination of the previously described genera in order to establish the features of their endosiphuncles. Indeed, such features are required to differentiate the slightly curved siphuncles of *Clitendoceras* and *Mcqueenoceras* from such genera as *Kirko-*

ceras, based on isolated siphuncles. The results of this investigation of the genera are presented here only insofar as they are relavent to the faunas of the Maryland section.

The endoceroids here described are all slender forms, endoceroid in aspect, rather than piloceroid. The present study contributes nothing to the nature of the siphuncle wall. The apical ends of the siphuncles, known for a number of the species and genera, are small and slender, completely consistent with those known in the Proterocameroceratidae, and contrasting strongly with those of the true Endoceratidae. Most if not all of these genera appear to belong to the Proterocameroceratidae. Whether it will be advisable to assign some to the Manchuroceratidae, as previously was done with *Coreanoceras*, or whether perhaps additional families will be needed, it is evident that none fulfill the requirements of the family Endoceratidae.

In one respect the present material proved highly vexing. Silicification was often incomplete. Etching had removed unsilicified portions of the siphuncles. Such specimens proved extremely friable and difficult to handle. Uncertainty as to whether small fragments pertained to one or to many individuals made it unsafe to attribute to a species based upon one part attributes shown by another, unless of course, the specimens actually fitted together. Breaks through the material of the endocones would sometimes show only a hollow cavity; again they were filled solid with granular silica. Specimens preserving the tubes are rare, and those showing any indication of the blades are exceptional. In treating the El Paso materials these handicaps have been overcome. Removal of unsilicified internal parts has been prevented by masking exposed portions of siphuncles with wax. The masking has to be reexamined and augmented several times as etching progresses. In this way, however, specimens are obtained showing internal features of the endosiphuncle which are lost by simple etching. I note these points as a guide to future preparation of similar materials.

The materials upon which this study is based contained endoceroid siphuncles which were evidently quite unlike any previously noted. Two genera, *Stenosiphon* and *Phragmosiphon*, are based upon siphuncles distinctive for strongly compressed cross section, and further differentiated by peculiarities of the section of the endosiphocone, position of the tube, and organization of the

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EXPLANATION OF PLATE 19

FIG. *1–4—Escharendoceras eccentricum*, n. sp. Holotype, no. 10. *1*, Ventral side; the true venter is the surface to the right of the submedian ridge. *2*, Lateral view, venter on left. *3*, Dorsal view. *4*, Adoral view, oriented as in fig. 1, true venter at lower right. *Archeosyphia* zone. (p. 85)

5–13, 15, 16—Escharendoceras simplex, n. sp. Paratype, *5*, dorsal view, *6*, lateral view, venter on left, *7*, adoral, venter on left *8*, ventral view. Holotype, *9*, ventral view, *10*, lateral view, venter on left, *11*, adoral view, venter on left, *12*, dorsal view. *13*, Paratype, an apical portion, ventral view. Paratype, *15*, lateral view, venter on right, *16*, ventral view. No. 11. *Archeoscyphia* zone. (p. 86)

14, 26–28, 30—Platysiphon expansum, n. sp. Holotype, *26*, ventral view, *27*, lateral view, venter on left, *14*, adoral view, venter on left, *28*, dorsal view, *30*, internal view showing endocone. No. 12, probably *Archeoscyphia* zone. (p. 84)

17–22—Phragmosiphon septiferum, n. sp. *17*, *18*, Two adoral views of paratype, slightly oblique, with venter on right; *19*, Dorsal view, *20*, lateral view, venter on right. Holotype, *21*, adoral and *22*, adapical views. *Lecanospira* zone, nos. 6 and 7. (p. 81)

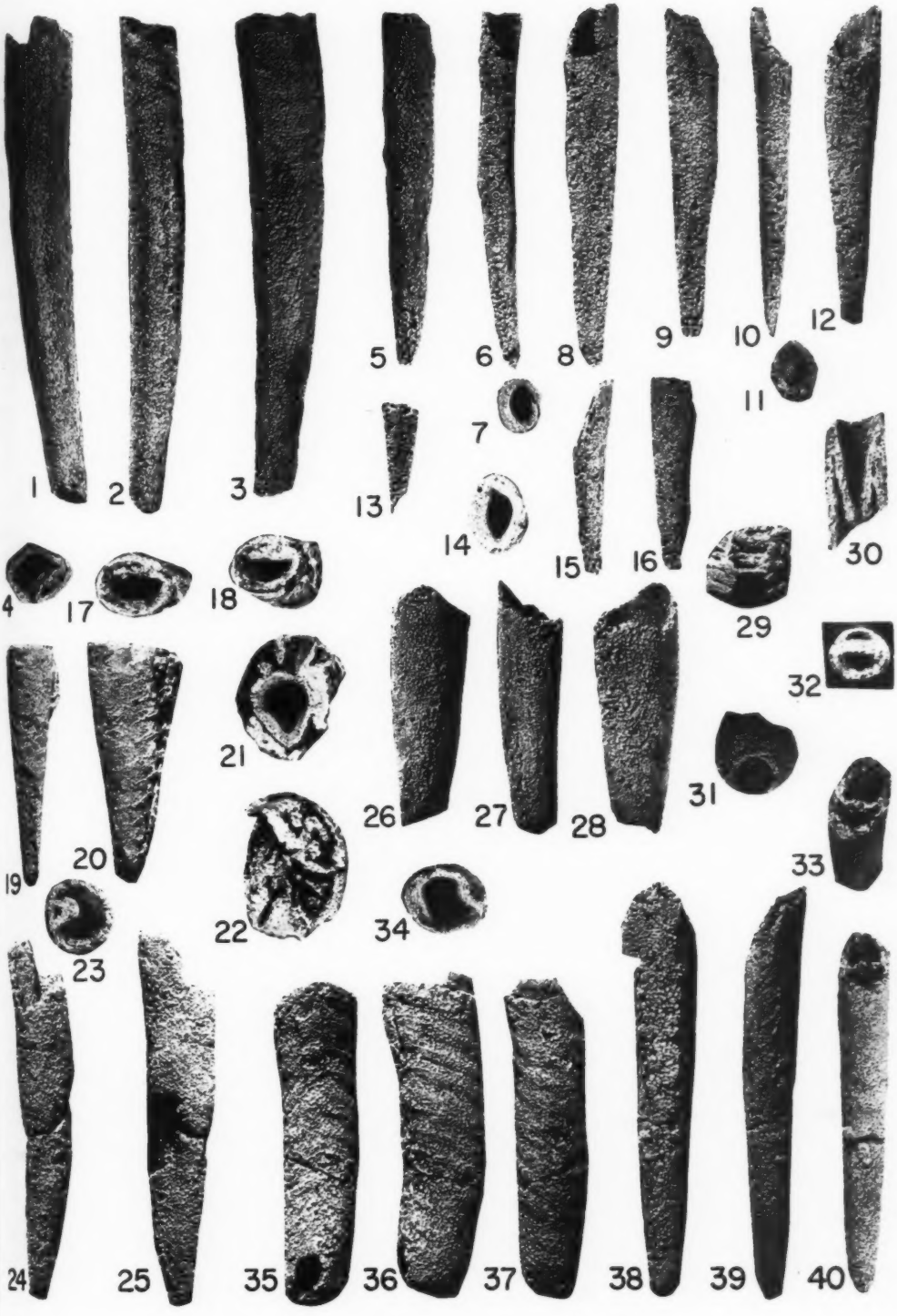
23–25—Clitendoceras anomalum, n. sp. Paratype, *23*, adoral view, venter on left; *24*, lateral view, venter on left; *25*, ventral view. No. 23, *Archeoscyphia* zone. (p. 88)

29, 31—Wolungoceras? sp. 29, Ventral and *31*, apical views. Lower half, Rockdale Run formation. No. 17. (p. 81)

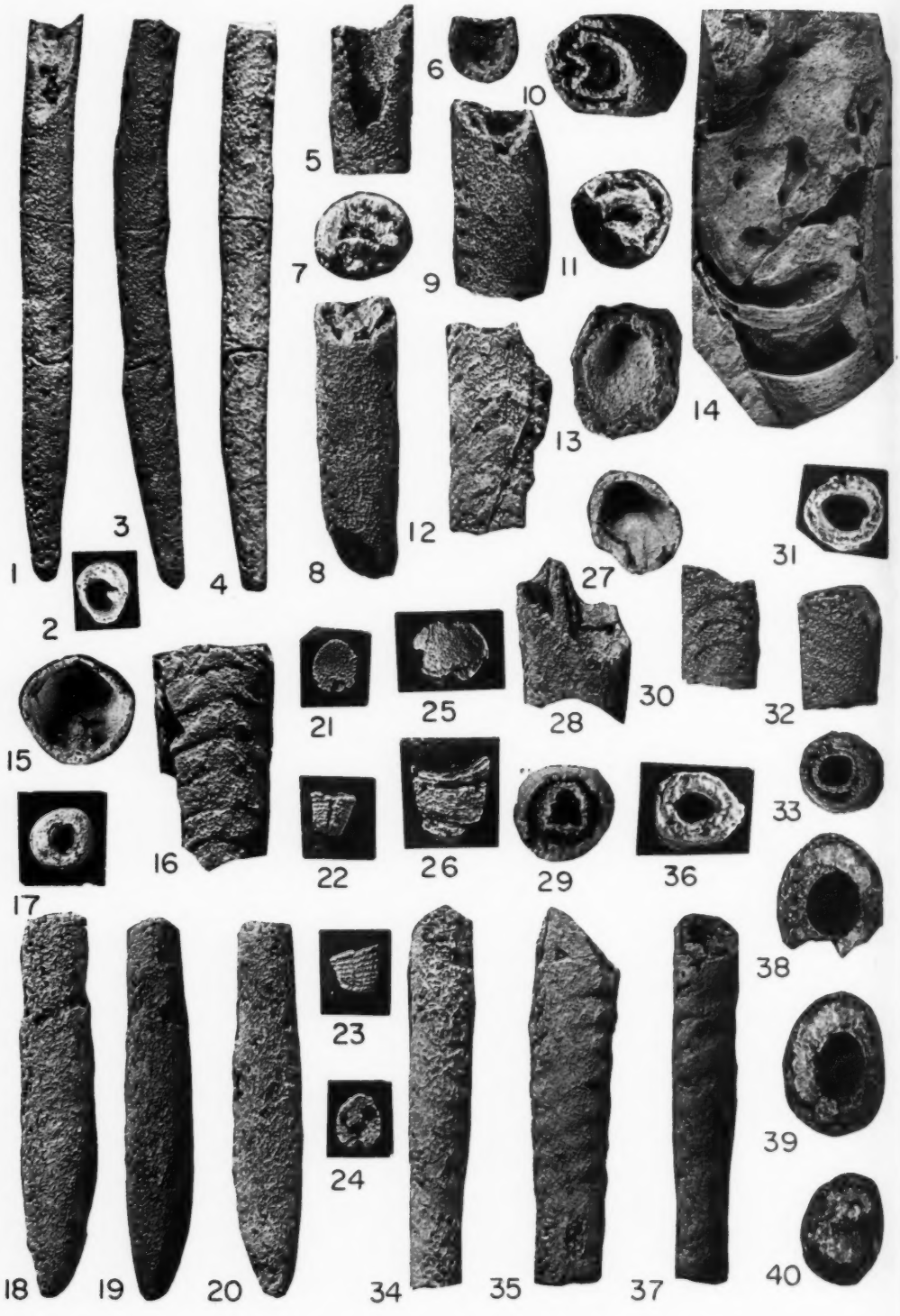
34–37—Pliendoceras concavum, n. sp. Holotype, *35*, ventral view, *36*, lateral view, venter on left *34*, adoral view, same orientation as fig. 36; *37*, dorsal view. No. 20, *Lecansopira* zone (?). (p. 90)

32, 33, 38–40—Retroclitendoceras depressum, n. sp. Holotype, *38*, ventral view, *39*, lateral view, venter on right, *40*, dorsal view, *33*, oblique dorsal, *32*, adoral, venter beneath. (p. 90)

(Fig. 40, ×1.3; all others ×1.5)



Flower, Canadian cephalopods, Maryland



Flower, Canadian cephalopods, Maryland

blades. *Escharendoceras* is based upon a siphuncle askew in its cross section. Quite evidently the phragmocone also was asymmetrical. Other genera, *Retroclitendoceras*, *Pliendoceras*, and *Lobosiphon*, are distinguished mainly upon peculiarities of the endosiphocone and the position of the tube. On the same basis, it has been possible to recognize such genera as *Coreanoceras*, *Mcqueenoceras* and *Clitendoceras*, originally differentiated on the basis of features of the conch and phragmocone without much attention given to the endosiphuncle. It should be noted that although a number of the genera here described as new are monotypic, other species have been found largely in the El Paso limestone. Their description is delayed awaiting the preparation and study of larger collections from the various isolated regions in which the formation outcrops in New Mexico. At present, *Lobosiphon*, *Escharendoceras* and *Platysiphon* have been recognized in this material, as well as the previously described genera *Proterocameroceras*, *Clitendoceras*, *Mcqueenceras*, and other genera not relevant to the discussion of the Maryland faunas.

For information on localities and horizon I am completely indebted to Dr. W. E. Sando. He will publish separately a comprehensive study of the stratigraphy and faunas of this region. It seems necessary here to present a brief summary of his stratigraphic interpretation in order to show the stratigraphic position of the cephalopods.

The lower 750′ of the section comprises the Stonehenge formation, of Gasconade age. The few cephalopods from this part of the section belong to the Ellesmeroceratidae, a family almost completely confined to this part of the column. These species are largely described without extensive systematic discussion, as a larger work on the Ellesmeroceratidae is now near completion. The Stonehenge species here described are, *Ellesmeroceras* (*Metaellesmeroceras*) *anomalum*, *Dakeoceras* sp., and *Oneotoceras? marylandicum*.

The overlying beds which Sando is naming the Rockdale Run formation, comprise 2400′ of section. He has recognized within it the *Lecanospira* zone, 200–560′ above its base. This horizon has yielded many siphun-

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EXPLANATION OF PLATE 20

FIG. *1–4*—*Clitendoceras anomalum*, n. sp. Holotype, ×1. *1*, Dorsum, *2*, adoral, dorsum on left, *3*, lateral, dorsum on left, *4*, ventral views. No. 22. *Archeoscyphia* zone. (p. 88)

5, *6*—*Lobosiphon inexpectans*, n. sp. Holotype, ×2. *5*, Ventral view, *6*, adoral, dorsum beneath. No. 21. *Archeoscyphia* zone. (p. 91)

7–11—*Coreanoceras lunatum*, n. sp. *7*, Apical view of holotype, no. 30. *8*, *11*, Lateral and adoral views of paratype, no. 31. *9*, Lateral view, venter on left, and *10*, adoral view, venter on left, of paratype, no. 29. *Archeoscyphia* zone. All ×2. (p. 92)

12, *13*—*Clitendoceras* sp., aff. *C. anomalum* Flower. *12*, Ventral view. *13*, Adoral view, venter beneath. ×2, *Lecanospira* zone. (p. 89)

14—*Oneotoceras? marylandicum*, n. sp. Holotype, ×1, lateral weathered surface. Stonehenge limestone. No. 2. (p. 80)

15, *16*—*Clitendoceras* sp., aff. *C. anomalum* Flower. *15*, Adoral view, venter beneath. *16*, Ventral view. ×2, *Lecanospira* zone. (p. 89)

17–20—*Mysticoceras fusiforme*, n. sp. Holotype, ×1. *17*, Adoral view, venter on left. *18*, Venter, *19*, lateral view, venter on left, *20*, dorsum. (p. 87)

21–26—*Clelandoceras* sp. Series of fragmentary phragmocones, ×2. *21*, Adoral and *22*, ventral views of one specimen. *25*, *26*, Adoral and lateral views of large phragmocone. *23*, Lateral view of another specimen. *24*, Adoral view of an isolated camera. Top of *Syntrophopsis* zone, no. 8. (p. 80)

27–29—*Clitendoceras* sp., aff. *C. anomalum* Flower. ×2. *28*, Dorsal view, showing projection of preserved ventral wedge. *27*, Adoral view, venter beneath. *29*, Apical view, same orientation showing semicircular section of cone. (p. 89)

30–33—*Stenosiphon sandoi*, n. sp., Paratype. *30*, Venter, *32*, lateral view, venter on left, *31* and *33*, adoral and adapical views, venter on left. No. 5. *Archeoscyphia* zone. (p. 83)

34–40—*Stenosiphon sandoi*, n. sp. Holotype, *34*, dorsum, *35*, lateral view, dorsum on left, *37*, venter, all ×1; *38*, anterior view, venter below, *39*, cross section at break near adoral end, *40*, cross section at break at midlength, showing tube and blades, ×2. No. 4, *Archeoscyphia* zone. (p. 83)

cles, but unfortunately silicification was poor, being largely confined to the outer surfaces of the siphuncles, and the material was largely too fragmentary to yield many valuable results. *Phragmosiphon* is confined to this horizon, *Clitendoceras* is well represented, and *Escharendoceras* may be present there. Sando has later emended this to include the *Pliendoceras* and *Mcqueenoceras*. I regard the validity of the emendations as doubtful.

The succeeding *Archeoscyphia* zone has yielded most of the cephalopods of the present study, including *Proterocameroceras, Mcqueenoceras, Coreanoceras, Pliendoceras, Lobosiphon, Retroclitendoceras, Clitendoceras anomalum, Mysticoceras, Platysiphon,* and *Escharendoceras simplex.*

The succeeding *Diparalasma* zone has yielded no identifiable siphuncles. It occupies an interval 770–1490 (more recently emended to 790′–1420′) above the base of the formation.

The *Syntrophopsis* zone, 1560–2070′ above the base, yielded no good endoceroids, but did yield from near its top phragmocones of the genus *Clelandoceras*, previously known only from the Smithville formation of Arkansas. The overlying Pinesburg Station dolomite has yielded no cephalopods.

Dr. Sando informs me that the Canadian section contained coiled cephalopods, evidently members of the Tarphyceratida, as might be expected, but that they defied extraction. The known fauna is obviously incomplete, and consists in the Rockdale Run formation of only those forms which were silicified and could be removed from the matrix by etching. It is notable that, though there were many small and a few large endoceroid siphuncles, there were none which, either by dimension or by rapid expansion, could be classed as piloceroids in the broad sense.

The materials here described were presented by Dr. Sando to the writer, and are to be deposited in the collection of the New Mexico Bureau of Mines. Individual numbers, on the specimens, are catalogue numbers made individually for this collection, and have been required to retain the identity of specimens which were so similar in gross proportions.

To conserve space in the following descriptions, localities have been given in terms of several of Sando's sections. The explanation of these sections is given below:

Section 1. Along abandoned Chesapeake and Ohio Canal between Pinesburg Station and Charlton, Maryland. Section begins at top of the Canadian exposed in face of river bluff which forms southern boundary of abandoned quarry located about 1000 feet southwest of railroad crossing at Pinesburg Station.

Section 2. Near Hicksville, Maryland. Section begins at top of the Canadian in pasture on west side of Spickler road, 0.3 mile south of intersection with Hicksville road.

Section 3. Section begins at top of the Canadian on Suffecool farm located 0.8 mile N25W of Pinesburg Station, Maryland.

SYSTEMATIC PALEONTOLOGY

Family ELLESMEROCERATIDAE

Genus ELLESMEROCERAS Foerste

Subgenus METALLESMEROCERAS, n. subgen.

Genotype: *Metaellesmeroceras anomalum* Flower, n. sp.

This subgeneric group is erected for forms which resemble *Ellesmeroceras* in general form and proportions. The siphuncle wall is composed of septal necks which are hemichoanitic, and not achoanitic as in other and apparently typical species. The only other obvious difference found has been in the cross section of the siphuncle, which is much broader than high; in typical *Ellesmeroceras* it is circular.

The length of the septal neck is sufficient actually to warrant the erection of a new group of generic rank. The reasons for designating it instead as a subgenus, are practical, and perhaps not altogether valid. Appalling difficulties would be encountered in separating the known species formerly assigned to *Ellesmeroceras*. Most of the material from which that genus is known consists of silicified specimens, from which the nature of the siphuncle wall cannot be ascertained. It is not even absolutely certain that *E. scheii*, the genotype, has achoanitic necks as has been assumed, since its siphuncle wall has never been made known in sufficient detail. The circular

rather than depressed cross section of the siphuncle leads me to believe, however, that it has the extremely short septal necks which I have observed in eight species known from material preserved in limestone, in which the necks have been well preserved.

ELLESMEROCERAS (METAELLESMEROCERAS) ANOMALUM, n. sp.
Pl. 22, fig. 23–26

The type and only known specimen is a portion of a phragmocone of a straight, moderately expanding cephalopod, compressed in section, the sutures closely spaced, and with lateral lobes. The type is 40 mm. in length, irregularly broken at either end. One dorso-lateral surface is obscure and probably incomplete. The shell expands from 7 and 8.5 mm. to 13 and 14 mm. in the basal 25 mm. In cross section the venter is only slightly more narrowly rounded than the dorsum. The surface shows fine transverse imbricating lines which confuse the surface pattern, and which apparently result from exfoliation of the shell wall. The lateral lobes of the sutures are symmetrical in lateral view, but actually steepen into extremely high saddles on the venter, a fact not apparent in lateral view. The dorsum shows no such steepening of the saddles, which are there low and inconspicuous in dorsal view. The siphuncle is broadly depressed in cross section, at the anterior end of the specimen, the only place at which the section is evident. There, where the shell is 14 mm. high and 13 mm. wide, the siphuncle is 4 mm. wide and 3 mm. high. The siphuncle was exposed by grinding away the ventral surface of the adapical half of the specimen. Here four camerae occur in a length of 6 mm. The septal necks, represented by light calcite, extend for half the length of a siphuncle segment. The darker connecting rings are relatively thin, and fail to show clear structural differentiation, though they are twice the width of the neck in thickness. The interior of the siphuncle is filled with matrix; no diaphragms are evident. Their absence is probably not significant, as diaphragms are found to be confined to extreme apical parts of the siphuncle in typical *Ellesmeroceras* species, and the present species is known only from a short portion of a phragmocone which, from all analogy, was quite close to the living chamber. Indeed, matrix at the adoral end of the specimen suggests that the extreme base of the living chamber may be preserved.

The holotype, no. 1 of the present collection, is from the Stonehenge limestone of Sando's section 5, 186′ below the top of the formation, about 1 mile south of St. Paul's Church, on the Forsythe and Eby farms.

DAKEOCERAS? sp.
Pl. 22, fig. 15, 16, 20–22

The specimens figured under this name consist of four tiny silicified specimens, representing fragments of a siphuncle of an ellesmeroceroid cephalopod. They are slender, slightly curved, and are remarkable mainly in that their surfaces excellently show curved surfaces, representing diaphragms. The largest is slightly compressed and curved, increasing in height from 1.5 to 2.5 mm., and a width of 2 mm., in a length of 4 mm. The adoral end is concave, representing a diaphragm, and two others can be seen in the length of the specimen, while the apex, though granular and rather rough, appears to represent another diaphragm, from its roughly rounded condition. A second smaller specimen 3.5 mm. in length is 1.5 mm. wide and 2 mm. high adorally. The adoral end is again concave, representing a diaphragm; a suture in the middle indicates a second, and the rounding of the apex indicates a third. Several smaller fragments are of similar proportions.

Discussion.—The above specimens are remarkable largely in that they represent an unusual phase of preservation. Diaphragms are usually indicated in silicified material in dolomite only by the rounded apex of the material filling the siphuncle from its adoral end. Ordinarily calcite has filled in the spaces between the diaphragms, and it is usually dissolved with the shell parts leaving as silicified specimens only the matrix filling the shell. The presence of diaphragms even in such a fragmentary specimen, is sufficient to indicate that the shell belongs to the Ellesmeroceratidae and that its age is almost certainly lower Canadian (=Gasconade in the broad sense). Though a very few younger genera are assigned to the Ellesmeroceratidae (Flower, 1954), only one

of them, *Cumberloceras* is known to possess diaphragms. The siphuncles of *Cumberloceras* are quite rapidly expanding. *Cumberloceras* is known from *C. buttsi* and *C. elwayense* from the Longview limestone of Virginia, and *C.* sp., from the Jefferson City dolomite of Missouri. Examination of the types has shown that the specimen figured by Cloud & Barnes [1948, pl. 41, fig. 38, 39, 43, and later described as *Burenoceras pumilum* by Unklesbay (1954)] is a diminutive *Cumberloceras*, and not a member of the genus *Burenoceras*.

The present species is a curved slender siphuncle. In form it is closest to siphuncles of the genus *Dakeoceras*, and I have tentatively referred it to that genus. The specimens are so fragmentary that it seems pointless to apply a specific name to them.

The figured specimens, no. 3 of the present collection, are from 130′ below the top of the Stonehenge limestone, from Sando's section 1.

ONEOTOCERAS? MARYLANDICUM, n. sp.
Pl. 20, fig. 14

Shell small, compressed, rapidly expanding vertically, curved, radius of curvature 40 mm. for the venter, about 90 mm. for the dorsum. Shell 15 mm. high at base, estimated width 14 mm., one side being weathered and the cross section somewhat obscure. The shell height increases to 22 mm. in the length of the phragmocone, 12 mm. ventrally, 24 mm. dorsally. The living chamber attains a height of 26 mm., with a dorsal length of 22 mm.; the anterior end is evidently incomplete.

Sutures with lateral lobes, the dorsal saddle appears to increase in prominence as growth progresses. The camerae are very shallow, averaging 1 mm. in depth. The siphuncle, exposed by weathering expanding conically. In one interval, where the surrounding camerae are lost by solution, the siphuncle increases in height from 3 to 4 mm. in a length of 7 mm.

A section taken at the base of the specimen indicated that weathering had so affected the whole siphuncle that its wall structure could not be ascertained, therefore no longitudinal sections were made. The cross section at the base indicated that there was no lateral groove there, which is the essential characteristic of *Oneotoceras*. A break in the middle of the specimen did indicate such a concavity on the unexposed lateral surface. It was irregular, and might conceivably be adventitious. Therefore the reference of the species to *Oneotoceras* is tentative.

Discussion.—This specimen consisted of a weathered lateral surface when received. It was evident from general proportions that it is related to species assigned to *Oneotoceras*, *Conocerina* and to *Clarkeoceras*. The close septa and rather rapidly expanding siphuncle suggest *Oneotoceras*, within which are already known species in which the lateral concavity of the shell is absent in young stages and sometimes even poorly developed in the adult stages.

The holotype, no. 2 of the collection, is from 225′ above the base of the Stonehenge limestone, from 0.5 miles N65E of St. Pauls Church, Mayland.

CLELANDOCERAS sp.
Pl. 20, fig. 21–26

Clelandoceras is represented by a series of silicified internal molds, all representing portions of phragmocones of a tiny cyrtocone of compressed section, very closely spaced septa showing faint lateral lobes, and a small tubular siphuncle close to the concave ventral side of the shell. The height of the shell is about 1 mm. greater than the width in all fragments, though there is some slight variation in cross section, and the dorsal, antisiphonal side, is consistently slightly more narrowly rounded than the ventral side. Stages are known ranging from 2 and 3 mm. to 5 and 6 mm. One specimen increases from 2 and 3 mm. to 4 and 5 mm. in a length of 4.5 mm.; another increases from 4 and 5 mm. to 5 and 6 mm. in 5.5 mm. This specimen contains eleven camerae. The siphuncle in all specimens is represented by a very small tubular cavity very slightly removed from the venter.

Discussion.—These tiny phragmocones appear to be quite characteristic of the highest Canadian fauna found in the Maryland section. The very close and flat septa are so suggestive of some tiny species of *Cyclostomiceras*, that I at first identified the specimens in terms of that genus. However, that genus shows neither the endogastric

curvature nor the compressed cross section which these specimens show; both of these features characterize *Clelandoceras*. For lack of better suggestions, *Clelandoceras* is retained in the family Ellesmeroceratidae, thought it must be pointed out that the genus remains still most inadequately known structurally. The genus has been known previously from two species, *C. dongatum* and *C. breve*, both from the Smithville formation of Arkansas. (See Ulrich, Foerste, Miller & Unklesbay, 1944 p. 134–5.)

The figured specimens, no. 8 of the present collection, are from 296′ below the top of the Rockdale Run formation, from Sando's section 1. They occur at the top of the *Syntrophopsis* zone, and are among the youngest fossils found in the Canadian of Maryland.

Family BALTOCERATIDAE
WOLUNGOCERAS? sp.
Pl. 19, fig. 29, 31

Under this designation is described a species known only from a short portion of a phragmocone, straight, evidently slightly compressed in cross section, with a large ventral siphuncle, and sutures which are transverse, straight and closely spaced. The specimen has a maximum length of 9 mm., not including the curved septal surface at the base. Seven camerae occur in the length. Siphuncle circular, 4 mm. in diameter. Shell 9 mm. wide and 11 mm. high at the base. The compressed condition could be the result of slight distortion.

Discussion.—Though nothing can be ascertained concerning the structure of the siphuncle wall, this shell is evidently a baltoceroid, and such shells are so little known in the American Canadian that this specimen is worthy of note, even in its present fragmentary state. Unfortunately, without knowledge of the siphuncle structure, it is not evident even that this species belongs to the Baltoceratidae instead of the new family Thylacoceratidae (Teichert & Glenister, 1954). Reference to the Baltoceratidae is based upon two considerations: (1) the Thylacoceratidae are not known to have siphuncles which are relatively large in diameter; (2) it is not altogether certain that the Thylacoceratidae and Baltoceratidae may not eventually have to be merged into a single family. The few species and genera already known suggest some intergradation in both the length of the septal necks and the relative diameters of shell and siphuncle.

Reference to the Asiatic genus *Wolungoceras* is also tentative. This course seems preferable to the erection of a new genus upon the basis of the present fragment. *Wolungoceras* is defined as having a central siphuncle, a feature certainly not consistent with the present species. The central position of the siphuncle does not seem to be well corroborated by the description of the type species either.

The figured specimen, no. 17 of the present collection, is from a locality 1.55 miles N55E of St. Pauls Church, Maryland. It is from the lower half of the Rockdale Run limestone, and is believed to have come from the *Archeoscyphia* zone.

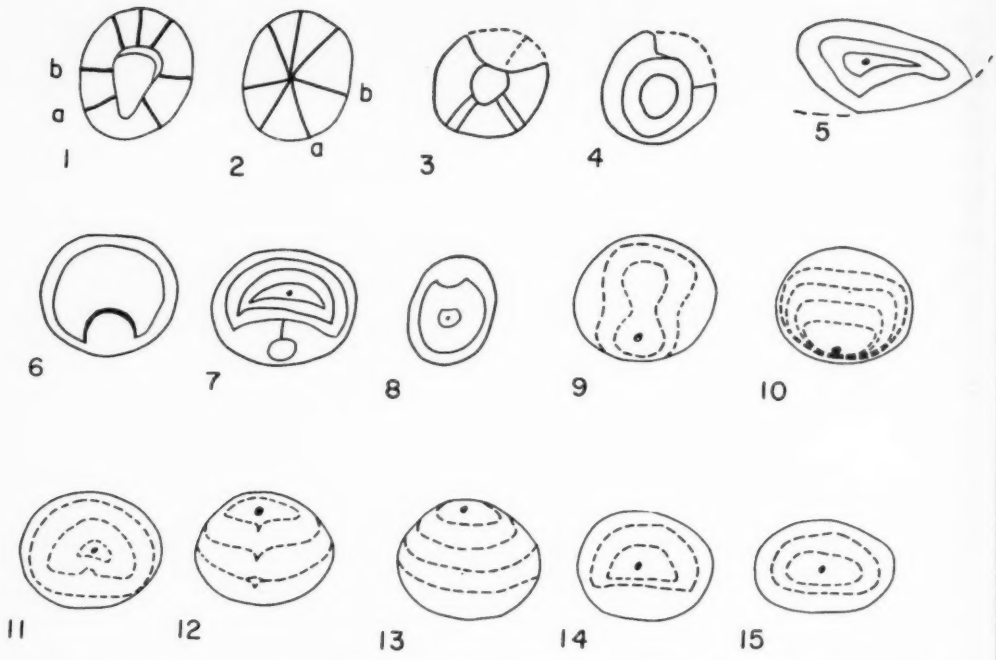
Order ENDOCERATIDA
Family PROTEROCAMEROCERATIDAE
Genus PHRAGMOSIPHON, n. gen.

Genotype: *Phragmosiphon septiferum*, n. sp.

Siphuncle externally simple, with the usual oblique septal markings, compressed in cross section, dorsum and venter about equally rounded. The cone is cuneate in cross section, the venter acutely angled, the oblique sides strongly flattened, dorso-lateral regions strongly rounded, and dorsum slightly flattened. It terminates in a centrally located simple tube. Cross sections show a remarkable number of blades, including a median dorsal blade, a pair of dorso-lateral blades, apparently uniform in position throughout the ontogenetic stages observed, and a variable number of lateral and ventro-lateral blades. A remarkable feature of the ventro-lateral blades is that as ontogeny progresses, they shift in position so that their juncture with the siphuncle wall is moved toward the dorsum.

PHRAGMOSIPHON SEPTIFERUM, n. sp.
Pl. 19, fig. 17–22; Text-fig. 1, 2

The holotype is a short portion of a siphuncle, compressed in section and very gently expanding. The figured portion is 27 mm. long, the maximum length of the frag-



TEXT-FIG. *1, 2*—Restored cross sections at anterior and apical end of type of *Phragmosiphon septiferum.*
3, 4—Apical and anterior ends of *Phragmosiphon* sp.
5—Diagrammatic section through siphuncle of *Escharendoceras eccentricum*, showing supposed region of contact with shell wall, contours on surfaces of endosiphocone and position of tube.
6, 7—Clitendoceras anomalum. 6, section near anterior end of endosiphocone, *7*, break near tip of cone, showing cones, blade, and ventral wedge. Both based upon the paratype.
8—Pliendoceras concavum. Section, showing contours on cone surface and position of tube.
9—Lobosiphon inexpectans, showing contours on cone surface and position of tube.
10—Retroclitendoceras depressum. Section, showing contours on cone and position of tube.
11—Proterocameroceras normale, contours on cone surface and position of tube.
12, 13—Mcqueenoceras cariniferum and *M. ventrale*, contours on cone surface and position of tube.
14—Generalized contour and tube pattern of *Clitendoceras.*
15—Cone and tube pattern of *Platysiphon expansum.*

ment, 34 mm. The siphuncle is too fragmentary for accurate measurement; the width is 12 mm. where the height is estimated at 15 mm. Rate of expansion not measurable, evidently very slight. Septal markings absent; surface smooth.

Endosiphocone cuneate, venter acutely angled, ventro-lateral regions flat, dorsum strongly rounded with a slight median flattening. The cone, of which a maximum of 29 mm. is preserved, probably extended forward for another 5 mm. It was obviously long and slender. A number of blades are preserved, passing from the siphuncle wall to the cone, or to the centrally located tube in which it terminates. A median dorsal blade is closely flanked by a pair of dorsolateral blades, uniform in position throughout the length of the specimen. Two ventrolateral pairs are remarkable in that their point of juncture with the siphuncle wall moved laterad and dorsad as growth progressed. The venter is incomplete; there is no evidence of a median ventral blade.

From section 1, 540′ above the base of the Rockdale Run limestone, uppermost part of the *Lecanospira* zone.

A paratype, from the same zone, 8 feet higher in the same section, is a rapidly expanding apical portion of a siphuncle, 27 mm. long, expanding uniformly to a height of 9 and a width of 3 mm. This specimen

shows clear septal markings, and a portion of the shell wall on the venter. The siphuncle was in contact with the shell wall. Seven septa occur in a length of 10 mm., the spacing being essentially uniform throughout the length of the specimen. Eleven can be made out on the length of the specimen; they slope strongly apicad from venter to dorsum, are strong ventrally, but obscure dorsally. The endosiphocone is complete, the specimen being obviously immature. The cone is markedly more narrowed on the venter than on the dorsum, but has not yet perfected the cuneate cross section shown in the much later stage of the holotype. The interior of the siphuncle is not exposed, no blades are therefore evident.

Discussion.—This remarkable species is unique in the compressed cross section, the numerous blades, and their arrangement.

Types and Occurrence.—Holotype from 540′ and paratype from 548′ above base of Rockdale Run formation, section 1, Washington County, Maryland. Both are from the uppermost beds of the *Lecanospira* zone.

PHRAGMOSPIHON sp.
Text-fig. 3, 4

Under this name I describe a small portion of a siphuncle only 9 mm. long, increasing from 8.5 to 9 mm. in width, evidently slightly compressed in cross section, but not as much so as in the preceding species. The specimen represents a fragment near the anterior end of the endosiphocone, which is compressed, less cuneate than the preceding form, slightly more narrowly rounded ventrally than dorsally. At the adoral end the cone is in contact with the ventral wall, a feature not indicated by the preceding species, though the apical end shows that the tube is certainly centrally located. A closely spaced pair of ventro-lateral blades is evident in the apical view, and one of the dorso-lateral blades which were widely separated. The middorsal region is missing. A vestigial structure suggests one of a second pair of ventro-lateral bands, most of which was lost by incomplete silicification and extensive etching.

Discussion.—Though this comes from the same horizon as the holotype of *P. septiferum*, it differs in so many ways (viz. the ventral position of the adoral part of the cone, the broader cross section of the siphuncle, the more rounded cross section of the cone) that it cannot be considered conspecific, particularly since many of these features are known in a still earlier stage of the paratype, indicating that the generalized features of the present specimen cannot be interpreted as a generalized early stage of *P. septiferum*. The compressed cone, the two pairs of ventro-lateral blades, and evidence of a dorso-lateral pair, show that the species is clearly a member of the genus *Phragmosiphon*.

Type, no. 16, collection of the writer. From section 1, 540′ above the base of the Rockdale Run limestone, *Lecanospira* zone, Washington County, Maryland.

Genus STENOSIPHON, n. gen.

Genotype: *Stenosiphon sandoi*, n. sp.

This genus is yet known only from isolated siphuncles, straight, slender, compressed in cross section, venter with a median flattening, dorsum uniformly rounded. Endosiphocone compressed, more narrowly rounded dorsally than ventrally, terminating in a slender central tube, central in position. A single pair of dorso-laterally located blades is present.

Discussion.—The compressed siphuncle, slightly compressed cone, narrowly rounded dorsally instead of ventrally, and the single pair of blades characterize this genus. Orientation is based on the septal markings, which are clear, and slope apicad from venter to dorsum. The structure of the siphuncle wall is unknown.

STENOSIPHON SANDOI, n. sp.
Pl. 20, fig. 30–40

The holotype is a portion of a compressed siphuncle 55 mm. long, increasing from a height of 10 and a width of 8 mm. at the base, where dorsum and venter are equally rounded, to 13 and 9 mm. where the venter is markedly flattened and the greatest width occurs well ventrad of the center of the siphuncle. Eleven annular markings suggest camerae 4 mm. in depth, a rather wider spacing in proportion to the siphuncle size than is indicated in associated endoceroids. Annular expansions are prominent ventrally, particularly on the ventro-lateral angles, but become fainter laterally, and disappear on the dorsal surface.

Endosiphocone compressed, more narrowly rounded dorsally than ventrally, conforming closely to section of siphuncle, slender, smooth, terminating in a central tube. A pair of dorso-lateral blades curve dorsal slightly as they approach the periphery of the siphuncle; they are nearly transverse where they join the tube.

A paratype represents a slightly later growth stage, and preserves a short portion close to the anterior end of the endosiphocone. It has a maximum length of 19 mm., and increases from 11 and 12 mm. basally to 12 and 14 in the basal 10 mm. The cone increases from 5 and 7 mm. basally to 7 and 9 mm. At the anterior end, the cone lies slightly closer to the dorsum than to the venter, a fact not evident from the holotype. Blades are not preserved in this specimen. A faint ridge is eccentrically placed on the surface of the endosiphocone, and is probably not a normal feature of the species.

Types.—Collection of the writer, nos. 4 and 5.

Occurrence.—Both specimens are from the upper part of the *Archeoscyphia* zone of the Rockdale Run formation. The holotype is from section 2, 748′ above the base and the paratype is from section 1, 790′ above the base of the Rockdale Run formation.

Genus PLATYSIPHON, n. gen.

Genotype: *Platysiphon expansum*, n. sp.

Endoceroids, known at present only from siphuncles, characterized by a very broad depressed cross section. Siphuncles are slender, relatively straight, though some specimens suggest a faint endogastric curvature. The endocones are simple, conforming with the cross section of the siphuncle wall, terminating in a central tube. No blades have yet been observed. Specimens so far known are replaced with rather coarse granular silica; blades may have been lost as a result of replacement, so their absence is not demonstrably a significant feature of the genus.

PLATYSIPHON EXPANSUM, n. sp.
Pl. 19, fig. 14, 26–28, 30; Text-fig. 15

This species is based upon a series of three incomplete siphuncles, strongly depressed in section, slightly more rounded dorsally than ventrally, very faintly endogastric, and quite rapidly expanding until they reach a height of 7 and a width of 9 mm., after which they become more slender, and the flattening of the cross section becomes more marked. Endocones are simple, terminating in a central tube. Annular markings are extremly faint on the exterior.

The holotype is 29 mm. long, increasing from 5 and 6 mm. to 7 and 9 mm. in the basal 13 mm., and then to 8 and 10 mm. in in the remaining 14 mm. (Pl. 19, fig. 14, 26–28.) The endocone is long, about 20 mm. long when complete. An unfigured paratype represents a later growth stage. It is a fragment 20 mm. long, increasing from 7 and 9 mm. at the base to 6 and 11 mm. adorally. A third specimen (Pl. 19, fig. 30) is a short portion of a siphuncle broken vertically, showing the long slender cone and its central termination. The fragment is 15 mm. long. Like the other specimens, it indicates a cross section in which the venter is much more markedly flattened than the dorsum.

Discussion.—The rapid intial expansion, large size, slight curvature in the early portion, and the character of the cross section characterize this species. Septal markings are too faint for measuring spacing of the septa accurately, but are sufficient to establish orientation of the specimens.

The holotype and two paratypes, no. 12 in the present collection, are from near the base of the section, probably in the *Lecanospira* zone, from an exposure in a pasture, 0.5 miles N65E of Charlton, Maryland. Possibly conspecific fragments are, however, from a much higher zone, from sections 1 and 2, near the top of the *Archeoscyphia* horizon, at 748′ and 790′ above the base of the Rockdale Run formation.

PLATYSIPHON GRACILE, n. sp.
Pl. 21, fig. 22–28

This is a *Platysiphon* the siphuncle of which is slender, straight, and very strongly flattened from the initial portion. The holotype (Pl. 21, fig. 2628) is a fragment 18 mm. long, showing oblique low rounded annuli, three occurring in 15 mm. The siphuncle increases from 4.5 and 6 mm. to 5 and 7

mm. in a length of 12 mm. Endocones simple, conforming to cross section of siphuncle, terminating in a tube slightly dorsad of the center. No blades are evident.

Three paratypes, more fragmentary, more coarsely replaced by silica, agree in rate of expansion and cross section, but fail to show annular markings, which of course may not be developed in the early stages represented by most of the specimens. Shells are slender, strongly flattened in cross section, down to a width of 1.5 mm.

The types, nos. 13 and 14 of the present collection, are from the *Archeoscyphia* zone of the Rockdale Run formation. The holotype, from section 3, occurs at 748′, the paratypes from section 3, at 757′ above the base of the fromation.

Platysiphon sp.

Two fragmentary siphuncles represent a species with a siphuncle which is straight and slender at a stage where *S. expansum* is rapidly enlarging and slightly curved, and slightly less strongly depressed in cross section than either *P. expansum* or *P. gracile*. The most complete expands from 6 and 7 mm. to 6 and 8 mm. in 15 mm. It is only a hollow shell, representing the adoral thin edges of the endosiphuncle. A second fragment, 14 mm. long, in two pieces, 6 mm. high and 7 mm. wide adorally, retains a portion near the tip of an endocone, which is here close to the convex dorsal wall of the shell. The fragments are not considered adequate for the erection of a species.

Specimens numbered 15 in the present collection, are from section 1, 729′ above the base of the Rockdale Run limestone, in the *Archeoscyphia* zone.

Genus Escharendoceras, n. gen.

Genotype: *Escharendoceras eccentricum*, n. sp.

This genus is erected for endoceroids known as yet only from siphuncles. These siphuncles are strongly flattened, cuneate in cross section, gently curved, and the curvature and suture lines indicate that either the shell was curved asymmetrically, or else the siphuncle was located away from the normal plane of symmetry. The dorsal side, marked by sutures which form broad rounded lobes, is slightly convex, and marked by prominent angles on either side The opposite side bears a ridge, closer to the convex than to the concave side of the siphuncle, dividing the "ventral" side into two faces. It is not evident which of these is a flattening due to contact of the siphuncle with the shell wall. Symmetry of the endocones suggests that it is the face close to the concave side, for it is there that the endocones are prolonged into a flattened tongue which is analogous to that found in many endoceroids on the venter.

Nothing is known of the gross features of the phragmocone or of the structure of the siphuncle wall. Analogy indicates that the septal necks were probably short, and that the genus is a member of the family Proterocameroceratidae, allied to *Clitendoceras*.

To my knowledge, nothing similar to these curious, strongly flattened, slightly curved siphuncles has been recorded previously. The two species here described are from the Canadian of Maryland. The genus is present in the middle Canadian portion of the El Paso limestone.

The modification of cross section and suture on these siphuncles is curiously similar to the modification of the external sutures and cross section in the Devonian trochoceroids *Naedyceras* and *Gonionaedyceras*.

Escharendoceras eccentricum, n. sp.
Pl. 19, fig. 1–4; Text-fig. 5

The holotype is a silicified endosiphuncle 55 mm. long, slightly curved, cuneate in cross section. Septal markings curve gently apicad on the convex dorsal side. The ventral side is divided into two portions by a sharp ridge, giving the siphuncle in cross section the shape of a scalene triangle, the ridge being eccentrically placed on the "ventral" surface. Curvature of the cross section is such that one of these faces is slightly convex, the other slightly concave. The endosiphocone is constricted by a forward projecting wedge which lies against the concave of the two faces on the ventral side. This side is believed to be the true venter, and was probably in contact with the wall of the shell. It lacks faint septal markings which can be seen on the face to its left as oriented in Pl. 19, fig. 1. The termination of the cone appears to be either central, or slightly dorsad of the center. The apical end fails to

show any trace of the tube. The dorsum is so arched that the cross section may appear quadrilateral rather than triangular, but it is not divided into two faces as is the venter.

The siphuncle evidently is uniform in curvature, cross section and rate of expansion. It must have had a simple slender apex like that known in the Proterocameroceratidae, to which family the genus probably belongs.

The holotype, and only known specimen, expands in the length of 55 mm. from 3 and 4 mm. at the apex to 6 and 9.5 mm.

Type, no. 10 of the present collection, from section 1, Rockdale limestone, 790′ above its base, in the upper part of the *Archeoscyphia* zone.

ESCHARENDOCERAS SIMPLEX, n. sp.
Pl. 19, fig. 5–13, 15, 16

A series of four isolated siphuncles are known, slender, slightly curved, the ventral side concave in longitudinal view, the cross section slightly cuneate, the convex dorsal side rounded, a faint ridge off center dividing the opposite side into two regions. The askew nature of the cross section is far less marked than in *E. eccentricum*. Septal markings are not evident on the exterior. The endosiphocone is modified by a wedge placed against the ventral side; this is most prominent in the adoral portion of the cone. The termination of the cone is plainly well dorsad of the center.

The holotype, 35 mm. long, increases from 1 and 2 mm. at the base to 3 and 5 mm., and shows at the anterior end a well developed wedge with a faint linear groove eccentrically placed on its surface (Pl. 19, fig. 9–11).

One paratype, Pl. 19, fig. 5–8, is more complete adorally, is 40 mm. long, increasing from 1 and 2 mm. to 4.5 and 5.5 mm. The ventral wedge is obscure, largely because it is internal, the anterior thin wall of the endosiphuncle being more complete in this individual. A third specimen, incomplete, is 10 mm. long, attaining an adoral width of 3 and a height of 2 mm. The adoral end shows a cross section of the endosiphocone at approximately the middle of its length. This is plainly a younger individual. The cavity is concave ventrally in cross section because of the wedge. A fourth specimen 22 mm. long, attaining an adoral width of 4 mm., is abraded so that, though the ventral wedge persists, the remainder of the endosiphuncle near the anterior end of the cone is lost. The tube is here seen to be quite close to the dorsal wall. This specimen suggests the genus *Mcqueenoceras*, but differs from it in curvature, askew cross section, and the strongly depressed cross section.

The four types, numbered 11 in the present collection, are from Sando's section 2, from the lower part of the *Archeoscyphia* zone, 558′ above the base of the Rockdale Run formation.

Genus MYSTICOCERAS Ulrich & Foerste

Genotype: *Mysticoceras vicinum* Ulrich & Foerste

Mysticoceras ULRICH & FOERSTE, 1933, Denison Univ. Bull., Sci. Lab., Jour., vol 30, p. 280.
——, ULRICH, FOERSTE, MILLER & UNKLESBAY, 1944, Geol. Soc. Am. Special Paper 58, p. 127.

This genus is known only from isolated siphuncles, straight, short, fusiform. Septal markings are strongly oblique and supply the only criterion of orientation. The endocones are circular in section and, as far as known, are simple and terminate in a central tube. Nothing is known of the siphuncle wall structure or of the shape of the entire shell. Two species, *M. vicinum* Ulrich & Foerste and *M. marcoui* (Barrande) are from the Phillipsburg section of Quebec. The first is from the Hastings Creek formation; the second is probably from the same formation. Ulrich, Foerste, Miller & Unklesbay (1944) have tentatively placed *Nanno primaevus* Whiteaves in the same genus. Their suggestion is a good one, but the species is so inadequately known that its generic position is necessarily inferential.

The species described below does not contribute materially to our knowledge of the genus.

The family Suecoceratidae Shimizu & Obata is probably not valid; it is evidently a collection for short, more or less fusiform endoceroid siphuncles. The Canadian forms are of uncertain affinities, because their structures are as yet so very inadequately known. They are clearly not closely related to *Suecoceras*, which I place in the family Endoceratidae, and that they are even re-

lated closely to one another requires much closer corroboration.

It has been assumed that *Mysticoceras* had a short siphuncle and phragmocone. The evidence does not indicate such a conclusion as strongly as it might at first seem. The parts of the siphuncles known from the three known species include only part of the siphuncle in which endocones were developed. There could have been, as is known in other Endoceratida, a very long slender portion of phragmocone between this portion and the living chamber. The specimens may have come from animals which were relatively long slender orthocones. If such shells were found complete, their relationship with *Mysticoceras* would not be evident from casual examination. Material from the El Paso limestone shows that some endoceroids had siphuncles which expanded very rapidly initially, and then became tubular. Apical portions would be called piloceroids; later portions endoceroids. Most Canadian siphuncles not associated with short rapidly expanding shells (piloceroids in the broad sense) have slender apical siphuncles. Some do show slightly fusiform apical ends not unlike those of *Mysticoceras*, though on a smaller scale. For this reason it is believed that *Mysticoceras* is related to these shells, which are assignable, from all of the present incomplete evidence, to the family Proterocameroceratidae.

MYSTICOCERAS FUSIFORME, n. sp.
Pl. 20, fig. 17–20

Like all species previously referred to the genus, this one is known from an isolated endosiphuncle. The type is fusiform, expanding rather rapidly from a blunt tip to a height of 10 and a width of 9 mm., then contracting in the remaining 38 mm. to a height of 9 and a width of 7 mm. The surface is rough, and shows only the faintest traces of oblique septal markings. At the adoral end of the specimen is seen a cross section of an endosiphocone, which is slightly compressed, higher than wide, one end more narrowly rounded than the other. The narrowly rounded side of the cone is close to the side of the siphuncle which is nearly straight in vertical outline, the opposite side is gently inflated in outline basally, approaching the opposite side and gradually becoming parallel to it after the inflated region is passed. The assumption is that the straight side is ventral, the inflated one dorsal.

Discussion.—This species has the form of *Mysticoceras*, but is longer, the anterior end more tubular, than that of other known species. The endosiphuncle extended slightly farther forward originally. The whole aspect of the specimen supports the belief, noted under the discussion of the genus, that *Mysticoceras* may have been a rather blunt slightly inflated apical part of a siphuncle, belonging to a long slender shell of endoceroid aspect.

The present form, no. 9 of the present collection, is from Sando's section 1,790′ above the base of the Rockdale Run formation, in the upper part of the *Archeoscyphia* zone. It should be noted that the two previous species are from the Hastings Creek formation, probably lowermost middle Canadian, and certainly considerably older than the form described here.

Genus CLITENDOCERAS Ulrich & Foerste

Genotype: *Clitendoceras saylesi* Ulrich & Foerste

Clitendoceras ULRICH & FOERSTE, 1935, Denison Univ. Bull., Sci. Lab., Jour., vol. 30, p. 268. ———, ULRICH, FOERSTE, MILLER & UNKLESBAY, 1944, Geol. Soc. Am., Special Paper 58, p. 106. ——, FLOWER & KUMMEL, 1950, Jour. Paleont., vol. 24, p. 608.

Unfortunately the present description of species involved a revised concept of the genus, based upon a restudy of the genotype and several associated species, not as yet assembled in a paper for publication. *Clitendoceras* is an endoceroid characterized by slight endogastric curvature, a cross section which is circular or slightly compressed, sutures which slope forward to some extent on the dorsal side. Septal necks are short, connecting rings thick, in the early portions; in later portions the necks lengthen and become hemichoanitic to subholochoanitic. The siphuncle lies close to the ventral wall of the shell. It is circular in cross section, the endocones are projected forward on the ventral side so that the speiss, the internal mold of the endosiphocone, is flattened there. (Text-fig. 14.)

In the original description of the genus, the curvature of the shell was rather under-

emphasized and the siphuncle wall was assumed to be holochoanitic. Nothing was known of the pattern of the endosiphuncle. In both form and the nature of the endosiphuncle, *Mcqueenoceras* is very close to *Clitendoceras*, but the cross section is slightly broader, the endocone pattern somewhat more specialized, and though I have for some time regarded the genera as questionably distinct, further study has indicated that the separation of the genera is probably valid. *Kirkoceras* Ulrich & Foerste, 1935, is known only from isolated curved siphuncles. From the extant information, it would be impossible to distinguish them from siphuncles of a *Clitendoceras*. Unfortunately, preservation of the typical material, from the Manitou dolomite of Colorado, is quite poor. Similar and possibly conspecific forms from the El Paso limestone are better preserved, indicate that the section of the cone was simpler, and that there is a specialized pattern of blades, as yet unknown in *Clitendoceras*.

To some extent the siphuncles of both *Clitendoceras* and *Mcqueenoceras* approach those of *Proterocameroceras*, particularly in the cross section of the endosiphocone. In both *Clitendoceras* and *Mcqueenoceras* the siphuncles are slightly curved, the complex blades of *Proterocameroceras* are unknown. *Clitendoceras* has a very different organization of the siphuncle wall. *Mcqueenoceras* is distinguished by the extreme dorsal position of the tube.

I have found *Clitendoceras* very prevalent in beds in eastern New York associated with *Lecanospira*. It is again well developed in the Gorman equivalent of the El Paso limestone. It is not surprising to find it in the *Lecanospira* beds of the Maryland section. Of the species formerly placed in the genus, *Endoceras consuetum* Sardesson and *Cameroceras inopinatum* Stauffer of the Shakipee dolomite are of uncertain generic position, but not convincing members of *Clitendoceras* to which they were referred by Ulrich, Foerste, Miller & Unklesbay (1944). *C. messleri* Ulrich, Foerste, Miller & Unklesbay is more convincing as a species of *Cotteroceras* than of *Clitendoceras*. *C. montrealense* (Billings) and *C? stillwaterense* (Stauffer) are again inadequately known speciés, but what is known of them does not suggest *Clitendoceras* very closely.

CLITENDOCERAS ANOMALUM, n. sp.
Pl. 19, fig. 23–25; Pl. 20, fig.1 –4;
Text-fig. 6, 7

The holotype is an unusually complete silicified siphuncle (Pl. 20, fig. 1–4), 82 mm. long, slightly endogastric. It is blunt apically, expanding rapidly to a diameter of 9 mm. in the basal 25 mm., then contracts slightly, and in the adoral 50 mm. increases from 7 to 9 mm. The surface shows only very faint traces of oblique septal markings, sloping apicad from the concave to the convex side. Close to the adoral end three septal markings occur in a length of 5 mm. Farther apicad they are too faint for measurement, and they cannot be seen at all in the apical half of the specimen. The endosiphocone at the adoral end of the type is slightly depressed in section, the endocone material thicker on the venter than on the dorsum. The midventral region is modified by a strongly elevated, round, cord-like wedge which becomes faint toward the apex of the cone, suggesting that it is a structure which may have preceded the endocones in appearance. The tube is centrally located. The siphuncle is broken at several points. Erratic silicification and extensive etching have combined to obscure the internal features. The break nearest the apex shows a suggestion of two lateral blades, but this is not regarded as conclusive.

The paratype (Pl. 19, fig. 23–25) is a siphuncle apparently from a younger individual. From the apex to the anterior end, which shows the endosiphocone, it is 40 mm. in length and attains a diameter of 7 mm. The anterior end of the cone shows a cord-like wedge, even more massive than that of the holotype. The specimen is broken in the middle. The break shows crescentic cones, the ventral wedge, through which there is an indication of a vertical blade, the whole pattern being somewhat suggestive of that of *Coreanoceras* (Text-fig. 6, 7). The center of the cone, the tube, is essentially central in position.

The holotype is from blocks of limestone excavated for a house located 0.4 miles east of Spickler, Maryland, on U. S. route 40. The paratype is from the *Archeoscyphia* zone, 729′ above the base of the Rockdale Run limestone, from section 1. Holotype and paratype are nos. 22 and 23 of the present collection.

CLITENDOCERAS sp., aff. C. ANOMALUM
Pl. 20, fig. 12, 13, 15, 16, 27–29

Under this heading are described several portions of siphuncles showing endosiphocones. All stages are later, judging by their larger diameters, than the types of *C. anomalum*. The differences shown may well be of specific rank, but the material is too fragmentary to serve for the erection of species.

One specimen, shown in Pl. 20, fig. 12–13, a fragment 17 mm. long, 8 mm. wide, and possibly slightly wider than high in cross section, shows oblique suture markings, and a very faint endogastric curvature. The cone lacks the prominent cord of the true *C. anomalum*, but endocone material forms a thick flat wedge there. Near the apex of the cone, its section becomes triangular. The tube is central.

A second specimen, Pl. 20, fig. 15–16, shows a portion of a siphuncle 18 mm. long, slender, circular in section, 8 mm. in diameter. Six septal markings occur in the length of the specimen. They are modified ventrally as is common in siphuncles which are in contact with the shell wall. The endosiphocone here is quite different; the endocone material is thickened ventrally, but the section of the cone is rounded throughout its length. Both specimens are from section 1, from the *Lecanospira* zone, 548′ above the base of the Rockdale Run limestone.

A third specimen (Pl. 20, fig. 27–29) a fragment 12 mm. long with an adoral width of 7 mm., and a cross section very slightly depressed in section, shows the anterior part of an endosiphocone. The ventral wedge is striated, a faint median ridge at its apical end, while adorally a faint ridge comes to a sharp point, bounded by two adorally converging grooves. Septal markings are obscure, but are oblique, as is usual. This specimen is from the same horizon and section, 540′ above the base of the Rockdale Run limestone.

Another specimen, not figured, is a portion of a slightly curved siphuncle, slightly depressed in section, 7 mm. wide and 6 mm. high at the base, increasing by 1 mm. in a length of 15 mm. Oblique annular markings are present. The ventral part of the endosiphocone is broken, but is evidently thick, and near the apex the cone becomes triangular as in the first specimen described. This specimen is probably also from the *Lecanospira* zone. It is from near the base of a section 0.5 miles S40E of Charlton, Maryland, exposed in a pasture.

Discussion.—The specimens described above are fragmentary and very friable. Internal structure is lacking, and only the outer crusts of the siphuncles were silicified. Probably there are at least two species here, and probably both are distinct from *C. anomalum*, as they lack the prominent cord-like wedge of that species. This conclusion is strengthened by the fact that these specimens are from the *Lecanospira* zone, rather than the *Archeoscyphia* zone of *C. anomalum*. In the nature of the cone, they are more typical of *Clitendoceras*, and I refer them in terms of *C. anomalum* only because no other *Clitendoceras* has been found here even approaching the present specimens in proportions.

Locality and horizon data has been given in connection with the descriptions of the individual specimens. They are numbered 23, 25, and 26 in the present collection. Two specimens are included in no. 25, one of which was so friable that it crumbled, but the fragments show the vital features.

CLITENDOCERAS SUBGRACILE, n. sp.
Pl. 21, fig. 17–20

This is a small, very slender, slightly curved siphuncle, the holotype 50 mm. long, increasing from 5 to 6 mm. in diameter in the basal 10 mm., and remaining at 6 mm. for the rest of the length. Septal markings oblique, three in a length of 5 mm. near the adoral end of the specimen, not visible in the apical half of the siphuncle at all. The curvature of the siphuncle is gentle, and is largely evident in the apical half.

The adoral end of the type shows a section broken about two thirds of the distance from the front of the cone to its apex. The endosiphuncle material is thickened ventrally. Imperfect silicification and etching have removed some calcite from its center, producing a cavity there (Pl. 21, fig. 20) which is adventitious. The apical part of the cone is small and circular in section. The broken apical end shows structure poorly, but does indicate a ventral filling of the siphuncle as might be expected.

The proportions, the slender form and

slight curvature, distinguish this species readily from all associated forms. The type, no. 24 of the present collection, is from section 1, from the *Archeoscyphia* zone, occurring 697′ above the base of the Rockdale Run limestone.

Genus RETROCLITENDOCERAS, n. gen.

Genotype: *Retroclitendoceras depressum*, n. sp.

This genus, at present monotypic, is based on an endosiphuncle, slender, slightly depressed in cross section, slightly curved endogastrically, a condition which probably extended to the external shell. Apex of siphuncle blunt, rapidly expanding, the siphuncle then becoming very slender. The endosiphocone is strongly flattened on both the dorsal and ventral sides, the dorsal flattening being the greater. The cone terminates in a tube close to the ventral, and not the dorsal side of the siphuncle. In this respect *Platysiphon* is comparable, but the cross section of the siphuncle is much more flattened, and the cone conforms more nearly to the cross section of the siphuncle. *Clitendoceras*, similar in form of the siphuncle, has the endocone material projected forward on the ventral and not the dorsal side. *Allocotoceras* Teichert & Glenister (1953) is comparable, but the cone is strongly crescentic, the ventral side is not flattened, but strongly convex, and the dorsum slightly concave instead of flat.

RETROCLITENDOCERAS DEPRESSUM, n. sp.
Pl. 19, fig. 32, 33, 38–40; Text-fig. 10

This species is based upon an endosiphuncle 42 mm. long, extending from the blunt apex to the basal third of the endosiphocone. It is faintly endogastric, slightly depressed in section, expanding rapidly in the first 3 mm., to a height of 3 and a width of 4 mm., attaining 5 and 6 mm. at 17 mm. beyond the apex, and increasing to only 6 and 7.5 mm. in the next 15 mm. Septal markings clearly shown ventro-laterally; a portion of the shell wall attached to the siphuncle on the midventral region.

The endocone material extends far forward on the dorsum, the cone being essentially semicircular as seen at the adoral end of the specimen, and confined to the ventral side. The apex of the cone is close to the ventral side of the shell. Etching of the incompletely silicified siphuncle produced cavities in the endocone material. At the adoral end (Pl. 19, fig. 32, 33) there is the effect of a secondary cone which is purely adventitious. No blades can be made out, possibly because of extensive silicification.

The type, no. 28 of the present collection, is from the lower part of the *Archeoscyphia* zone, 547′ above the base of the Rockdale Run formation, from Sando's section 3.

Genus PLIENDOCERAS, n. gen.

Genotype: *Pliendoceras concavum* Flower, n. sp.

Only the endosiphuncle is known, which is slender, slightly endogastric, with the usual oblique septal markings, compressed in cross section. The endosiphocone is extremely deep and slender, terminating in a tube which is central or nearly so. Its cross section is modified by a cord-like wedge on the dorsal side, but otherwise conforms to the cross section of the siphuncle wall. Externally, the siphuncle resembles that of *Clitendoceras* except for the compressed section. The pattern of the endocones is almost exactly the inverse of that of *Clitendoceras anomalum*. *Allocotoceras* Teichert & Glenister (1953) is similar in the cross section of the cone, but is not compressed in section, nor is the siphuncle curved.

PLIENDOCERAS CONCAVUM, n. sp.
Pl. 19, fig. 34–37; Text-fig. 8

Holotype a slightly endogastric compressed siphuncle, 34 mm. long, expanding from 6 and 8 mm. to 9 and 11 mm. The basal part is broken, evidently prior to burial, the broken surface smooth and silicified. Septal markings oblique, five in a length of 9.5 mm. adorally. The venter shows evidence of contact with the shell wall. Cone slender, nearly complete, 13 mm. long, nearly complete adorally. The endocone conforms to the section of the siphuncle wall ventrally and laterally, but is thickened into a wedge on the dorsum, narrow, rounded and cord-like anteriorly, but apically its outline is absorbed in the endocone material so that the cross section of the cone is flattened dorsally. The cone terminates in a central tube. No trace of the endosiphoblades is apparent.

The holotype, no. 20 of the present collection, is from near the base of the section, 0.5 mile N65E of Charlton, Maryland, exposed in a pasture. The horizon is believed to lie at about the middle of the *Lecanospira* zone of the Rockdale Run formation.

Genus LOBOSIPHON, n. gen.

Genotype: *Lobosiphon inexpectans*, n. sp.

This genus is known only from a siphuncle as yet. The siphuncle is straight, slender, with oblique septal markings suggesting a position close to the ventral wall of the shell. Cross section circular. Endosiphocone becoming compressed in cross section as it nears its apex, the cavity dumbbell shaped, constricted in the middle, and widened and rounded both dorsally and ventrally. The ventral expansion is the larger of the two, and this one alone terminates in a tube which lies ventrad of the center of the siphuncle. The compressed dumbbell-shaped cone is unique among the endoceroids.

LOBOSIPHON INEXPECTANS, n. sp.
Pl. 20, fig. 5, 6; Text-fig. 9

The essential features by which this species is recognized are contained in the above generic description. The type is a fragment of a siphuncle 14 mm. long, circular in cross section, increasing in its length from 4.5 to 5.5 mm. Septal markings strongly oblique, very closely spaced, six in a length of 5 mm. Adorally the endosiphuncle is incomplete ventrally. Either endocone material was so thin there that it was lost, or it may have been altogether absent. Adorally the cone conforms to the siphuncle in cross section, but a lateral constriction appears gradually and becomes more marked as its apex is approached, the cavity being divided into a larger ventral and a smaller dorsal rounded region, narrowly connected. The ventral cavity alone terminates in a tube, which is located less than half way from the center of the siphuncle toward its ventral wall. No blades have been observed.

The section of the cone is completely distinctive for this form. It may be distinguished in the Maryland Canadian also by the strongly oblique and very closely spaced septal markings.

The holotype, no. 21 of the present collection, is from 757′ above the base of the Rockdale Run limestone, from section 3 of Sando. It occurs shortly below the top of the *Archeoscyphia* zone.

Genus COREANOCERAS Kobayashi

Genotype: *Coreanoceras kemipouense* Kobayashi

Coreanoceras KOBAYASHI, 1931, Japanese Jour. Geol. Geogr., vol. 8, p. 169. ——, KOBAYASHI, 1931, Geol. Survey Chosen, Bull., vol. 11, no. 1, p. 45. ——, KOBAYASHI, 1936, Japanese Jour. Geogr., vol. 13, p. 185–195, pls. 22–23. ——, ULRICH, FOERSTE & MILLER, 1943, Geol. Soc. Am., Special Paper 49, p. 18. ——, FLOWER & KUMMEL, 1950, Jour. Paleont., vol. 24, p. 608.

This genus has been regarded as a piloceroid, with a ventral siphuncle characterized by endocones of lunate or crescentic cross section, terminating in an essentially central tube. Endocone material forms a large ventral mass, its dorsal surface convex, and supposedly in the anterior end of this mass is a secondary endocone. Some differences in cross sections through the endosiphocone are shown, but a median ventral blade is often indicated.

In two respects it seems necessary to modify the above concept of the genus. First, the ventral alveolus or secondary cone unfortunately rests upon what could be easily, and probably are, phenomena resulting from solution, rather than original structures. Second, identification of the genus as a piloceroid leads one to look for the peculiar characters of the endosiphuncle in siphuncles which are relatively large and rapidly expanding. While some of the material shows siphuncles larger than that of many associated Canadian endoceroids, the siphuncles are not widely separated from members of the Proterocameroceratidae either in size or rate of expansion. In the present material are found some relatively small siphuncles which, by the internal features, are assignable to *Coreanoceras*. These siphuncles show some affinities with those placed in some other genera. Perhaps most closely similar is *Clitendoceras anomalum*. A cross section at the middle of an endosiphuncle, through the endosiphotube, shows features very similar to those of *Coreanoceras*. It is not placed in that genus because its curvature is evidently that of the siphuncle of a *Clitendoceras*, and it agrees quite

closely with other, if slightly more generalized, siphuncles of typical members of the genus.

Kobayashi has shown that the septal necks of *Coreanoceras* are hemichoanitic to subholochoanitic, at least in the region figured by him (1936) for *C. shorinense*. The siphuncle wall has not been observed in enough detail to show the structure in any other species. The phragmocone and shell wall are virtually unknown.

COREANOCERAS LUNATUM, n. sp.
Pl. 20, fig. 7–11

Three small fragmentary siphuncles form the basis of this species. The first is a fragment 15 mm. long, straight, slender, depressed, slightly more flattened ventrally than dorsally, 5 and 6 mm. basally, increasing to 6 and 7 mm. in 15 mm. Adorally the anterior part of the cone is shown; the specimen here has very much the aspect of a *Platysiphon*, for the cone is simple in cross section and conforms to the cross section of the siphuncle. As the cone is traced toward its apex, the ventral endocone material is seen to thicken more rapidly, becoming flat and then slightly convex in cross section. The apical view of the specimen (Pl. 20, fig. 7) shows a crescentic cone near its tip, a pattern characteristic of *Coreanoceras*. The siphuncle is rather coarsely silicified, and individual cones and the blades are not shown.

A second specimen (Pl. 20, fig. 8, 11) is a portion of a siphuncle with a maximum length of 26 mm., straight, slender, scarcely depressed in cross section, 8 mm. wide adorally. The anterior end shows again a cross section near the apex of the cone, which is crescentic and fails to differ from the section shown on the apical end of the preceding specimen in any essential feature. The broken section at the apical end of the same specimen has lost the essential structures as a result of etching of incompletely silicified material.

A third specimen, which is only tentatively assigned to the species, is a portion of a siphuncle which contracts slightly toward the anterior end. It is 26 mm. long, slender, and at its middle has a width of 19 and a height of 18 mm. The basal part of the cone, shown at the anterior end of the specimen, has the characteristic strongly lunate cross section. The apical end shows the central termination of the cone, but all structures in the endocone material have been removed by etching.

The three specimens are all from the same locality and horizon, from the *Archeoscyphia* zone, 729′ above the base of the Rockdale Run formation, from Sando's section 1.

Genus MCQUEENOCERAS
Ulrich & Foerste

Genotype: *Mcqueenoceras jeffersonense* Ulrich & Foerste

Mcqueenoceras ULRICH & FOERSTE, 1936, Denison Univ. Bull., Sci. Lab., Jour., vol. 30, p. 279. ——, ULRICH, FOERSTE & MILLER, 1943, Geol. Soc. Am. Special Paper 49, p. 143. ——, ULRICH, FOERSTE, MILLER & UNKLESBAY, 1944, Geol. Soc. Am., Special Paper 59, p. 119.
Proterocameroceras FLOWER & KUMMEL, 1950, Jour. Paleont., vol. 24, no. 5.

Endoceroids, endogastrically curved, sutures typically with lobes on the venter, otherwise straight. Siphuncle close to venter, typically endoceroid in external aspect, details of wall structure unknown. The anterior end of the endosiphuncle shows the endocone material drawn forward strikingly into a broad flat blade on the ventral side. The center of the cone, the tube, lies very close to the dorsal wall of the siphuncle. The endosiphocone cavity is rounded dorsally; indeed, the endocone material separating it from the primary siphuncle wall is thin, short, and sometimes vestigial. The ventral surface of the cone is strongly flattened.

Discussion.—This genus has undergone some curious vicissitudes involving some misunderstandings. Ulrich & Foerste (1936) correctly regarded the genus as an endoceroid, mentioning the peculiar form of the spiculum. Ulrich, Foerste & Miller (1943) classed it with the synthetic Cyrtendoceratidae, failing to recognize its affinities even though anterior portions of the endosiphuncle, exhibiting the characteristic pattern of the endosiphocone, were figured. In the next year Ulrich, Foerste Miller & Unklesbay recognized the endoceroid affinities of the genus.

The flattening of the ventral side of the endosiphocone leaves this genus with a pattern so similar to that of *Proterocameroceras* that I regarded it as a synonym of that genus

(Flower & Kummel, 1950). Restudy of the type and other material has led me to conclude that *Mcqueenoceras* is distinct enough to merit recognition as a separate genus. Curvature is slight among the species, and not always evident. However, the extreme anterior prolongation of endocone material on the venter, the flat dorsal surface of such a projection, together with the extreme dorsal position of the tube, supply a combination of characters distinguishing the genus from *Proterocameroceras*. On the basis of curvature, the genus may be confused quite easily with *Clitendoceras*. I am inclined to suspect a close relation between these two genera. *Clitendoceras* is typically somewhat narrower in cross section, has sutures which are uniformly oblique, instead of merely possessing a lobe on the ventral surface. Its siphuncle is similar externally to that of *Mcqueenoceras*. Comparison of the siphuncle wall structure is not yet possible; no sufficiently well preserved specimens of *Mcqueenoceras* have yet become available for study of the septal necks and connecting rings. The endosiphuncles of *Clitendoceras* tend to show a thickening of the wall of the cone on the venter, but it is never as extensive as in *Mcqueenoceras*, and the endosiphotube is never located close to the dorsal surface, nor is the endocone material on the dorsal side of the cone greatly reduced.

Mcqueenoceras contains only two previously described species which are proper members of the genus, *M. jeffersonense* of the Jefferson City formation of Missouri, and *M. newmanni*, of the Cotter formation of the same region. Cloud & Barnes (1948) have correctly assigned to this genus isolated siphuncles from the basal Honeycut formation of central Texas, the part of the section equivalent to the base of the Jefferson City formation. I have found similar forms characterizing the same horizon, almost to the exclusion of other fossils, in the section of the Franklin Mountains on the edge of El Paso, and have found the same forms well developed at the same horizon in several places in New Mexico, notably in the southern San Andres mountains. In central and western New Mexico this horizon may contain these forms unsilicified and in limestone, in which case their identification is not as easy, because the specimens cannot be removed by etching. In the Cooks Range and the Big Hatchet Mountains, these forms apparently disappear; the horizon is given over to stromatolite reef beds yielding little besides a characteristic *Orospira*.

Mcqueenoceras is an important genus stratigraphically, because it characterizes to an amazing extent a horizon low in the equivalents of the Jefferson City beds. *M. franklinense* Ulrich, Foerste, Miller & Unklesbay (1944) is not properly a member of this genus. A new generic name is elsewhere being proposed for this and some related forms. They are more akin to *Proterocameroceras* than to *Mcqueenoceras*, but constitute a separate generic group characterized, among other differences, by the broadly annular aspect of the exterior of the siphuncle.

MCQUEENOCERAS CARINIFERUM, n. sp.
Pl. 21, fig. 1, 2, 5–7; Pl. 22, fig. 1, 2, 5, 6; Text-fig. 12

This species is known only from isolated silicified siphuncles. They are moderately slender, slightly endogastric, septal markings fairly widely spaced. The dorsal surface of the long flat ventral blade or wedge marking the ventral side of the cone, is characterized by a shallow median groove.

The holotype (Pl. 21, fig. 5–6; Pl. 22, fig. 1–2) the most complete specimen observed, is 44 mm. long. The apex is abraded and incomplete, though quite probably very close to the original apex. The siphuncle is faintly depressed in section, increasing from 4 and 5 mm. at a point 5 mm. beyond the tip, to 7 and 8 mm. in a length of 25 mm. The anterior end is broken obliquely across the endosiphocone. Its cavity is flat ventrally, with a median ridge, there being a median linear depression in the surface of the ventral endocone material. Dorsal and lateral regions are rounded, conforming with the cross section of the siphuncle, faintly annular on the inner surface, a feature not observed in other specimens. The cone is incomplete, but obviously long and slender, and its termination is close to the dorsal wall of the siphuncle. The dorsal wall of the endosiphocone is thicker than in most other specimens; it is not evident whether this is because the cone is developed at a later

growth stage in this specimen than in others, or whether this feature may be variable in the species, or whether the species is drawn too broadly. Annular markings on the exterior of the siphuncle show the usual obliquity. Adorally ten septal markings occur in a length of 20 mm. The markings are fainter apically, but there is evidently very little change in their spacing.

A paratype (Pl. 21, fig. 1–2; Pl. 22, fig. 5–6) represents a siphuncle from an animal representing a somewhat earlier growth stage. This specimen, 38 mm. long, expands in the basal 15 mm. from 4 and 5 mm. to 6 and 7 mm. Orad of this point, the dorsal wall is missing, but the ventral wall extends forward for 12 mm., and originally extended 3 or 4 mm. more, as can be seen from the broken outline. The dorsal surface exposed here shows a median groove toward which the relatively flat lateral surfaces slope slightly. The tip of the cone is close to the dorsum. Endocone material on the dorsum extends only 3 mm. to the tip of the cone. The specimen is little if at all abraded; it is evident that the endocone material was extremely short on the dorsal side of the tube, extending orad from the tip of the cone only 3 mm., while on the venter it extended forward about 18 mm. Annular markings on the exterior of this specimen are vestigial. A third specimen (Pl. 21, fig. 7) shows much the aspect of the previous one, but is less complete. The proportions of the basal part of the endosiphocone are almost identical with those of the preceding form. This specimen has a maximum length of 16 mm., and attains a maximum width of 7 mm.

All specimens are from the *Archeoscyphia* zone of the Rockdale Run formation. The holotype, second figured paratype and one unfigured specimen, are from an elevation of 790′ above the base of the formation, all from Sando's section 1. The second paratype is from a recorded elevation of 757′, essentially at the top of the zone, from a locality 1.55 miles N55E of St. Pauls Church. Several other fragments tentatively identified with this species are also from the *Archeoscyphia* zone.

MCQUEENOCERAS VENTRALE, n. sp.
Pl. 21, fig. 3, 4, 7–9, 14–16; Pl. 22, fig. 3, 4, 13, 14; Text-fig. 13

Known only from silicified siphuncles which are slender, slightly wider than high in cross section, faintly endogastric. The tip of the endocone is extremely close to the dorsum, so that virtually no dorsal wall of the endosiphocone is seen in most specimens. The ventral side projects into a broad blade, rounded in front when complete. Its dorsal surface lacks a median groove found in the preceding form, but is very faintly concave. Septation of the exterior of the siphuncle is is not shown clearly in any of the specimens.

The holotype, no. 37 of the present collection, is a portion of a siphuncle 22 mm. long, preserving the anterior end of the ventral part of the endosiphuncle, which is smoothly and broadly rounded. The specimen is 22 mm. long. At the base it is faintly wider than high, measuring 5.5 and 6 mm. The width increases to 7 mm. in a length of 16 mm. The tube is tiny and less than 1 mm. from the dorsum. The wall of the cone extends forward from it only 1 mm., while it extends forward 15 mm. on the ventral side. As seen from the dorsum, the ventral surface so finely exposed is faintly concave but without markings (Pl. 21, fig. 3, 4; Pl. 22, fig. 13, 14).

Only the faintest traces of septal markings are seen on the type. They cannot be measured properly, but are evidently much more closely spaced than in the preceding species.

A second specimen (no. 38, Pl. 22, fig. 3, 4) 16 mm. long, increases from 3 and 4 mm. to 5 and 6 in 12 mm. The ventral side of the cone is exposed in dorsal view for the anterior 12 mm. of the specimen. The specimen is notable mainly in showing a relatively rapid rate of expansion, which may be expected, as it represents a portion nearer the apex of the siphuncle, and is evidently from a less mature animal than is the holotype.

Another fragmentary specimen (Pl. 21, fig. 8, 9) 12 mm. long, with a maximum width of 7 mm., shows the typical aspect of the endosiphocone, perfectly recognizable in spite of the fragmentary nature of the specimen. A fourth specimen (Pl. 21, fig. 14–16) 12 mm. long, and with a maximum width of 6 mm., is broken across the anterior end of the cone. Pl. 21, fig. 16 is oriented with the dorsum below; it is Pl. 21, fig. 15 viewed from the anterior side. The endocone is close to the dorsal wall and very small. Solution has removed the inner part of the endocone

material, producing a cavity within it which is not an original feature.

The types, nos. 37–41 of the present collection, are from the *Archeoscyphia* zone. The holotype and one unfigured paratype are from 1.55 miles N55E of St. Pauls Church, in the lower half of the section. The original of Pl. 21, fig. 8, 9, is from 757′ above the base of the Rockdale Run limestone from Sando's section 3. The original of Pl. 21, fig. 14–16, is from 790′ of section 1. Similar but poorly preserved specimens are from 548′ of the same section, an elevation which would bring them in the upper part of the *Lecanospira* zone. Their identification with this species is, however, somewhat uncertain from the present material.

Genus PROTEROCAMEROCERAS Ruedemann

Genotype: *Orthoceras brainerdi* Whitfield

Proterocameroceras RUEDEMANN, 1905, New York State Mus. Bull. 80, p. 325. ——, Ruedemann, 1906, ibid., Bull. 90, p. 405.
Cameroceras BASSLER, 1915, U. S. Nat. Mus. Bull. 90, vol. 1, p. 179.
Proterocameroceras KOBAYASHI, 1935, Geol. Soc. Japan Jour., vol. 42, p. 750. ——KOBAYASHI, 1937, Japanese Jour. Geol. Geogr., vol. 14, p. 15. ——, FLOWER, 1941, Palaeontographica Americana, vol. 2, no. 13, p. 28. ——, ULRICH, FOERSTE, MILLER & UNKLESBAY, 1944, Geol. Soc. Am. Special Paper 58, p. 71. ——, FLOWER, 1947, Ohio Jour. Sci. vol. 47, p. 162. ——, FLOWER & KUMMEL, 1950, Jour. Paleont., vol. 24, p. 608. ——, TEICHERT & GLENISTER, 1954 Bull. Am. Paleont., vol. 35, no. 150, p. 59.

Proterocameroceras is externally an extremely generalized endoceroid, slender, straight, slightly depressed in cross section, sutures straight or slightly modified. The siphuncle is ventral, its wall composed of achoanitic bifurcated septal necks and connecting rings composed of two layers, and relatively thick. The endosiphuncle has been described in detail by Ruedemann for the genotype. Characteristic are the semicircular endosiphocone, rounded above, flattened below, and the three blades. The enlargement of the siphuncle at the apex, and the interpretation of the shell as having only a siphuncle without septa for some distance is, from my observations, almost certainly based upon adventitious material.

Amazingly, up to the present the only American species assigned to this genus has been the genotype. Quite possibly this interpretation is in part due to the almost complete neglect given to features of the endosiphuncle by many workers. A number of other genera approach more or less close to *Proterocameroceras* in features of the endosiphuncle, notably *Clitendoceras* and *Mcqueenoceras*. Differences by which they can be distinguished from *Proterocameroceras* are noted in the discussion of *Mcqueenoceras*. The organization of the siphuncle wall is unique among endoceroids, or rather, appears to be in the light of our extremely incomplete knowledge of siphuncle walls in Canadian endoceroids.

PROTEROCAMEROCERAS NORMALE, n. sp.
Pl. 21, fig. 10–13; Text-fig. 11

This species is based upon a silicified endosiphuncle 30 mm. long, straight, slender, increasing from 4 and 5 mm. to 7 and 8 in the basal 25 mm., and attaining a maximum width of 7 mm. at the adoral end. Septal markings are extremely vestigial on the type. The endosiphocone is flattened ventrally; the endocone material projects forward nearly twice as far on the venter as on the dorsum; the ventral profile of the cone is straight. In cross section, the otherwise flat surface of the cone is seen to be modified by a small elevated rounded tube-like wedge. The cone terminates centrally. The dorsal wall is rounded in cross section, conforming to the cross section of the siphuncle. In vertical section the wall of the cone is slightly curved in profile. The anterior end of the specimen is broken into two parts. Pl. 21, fig. 10 (the specimen viewed from the dorsum) shows the anterior surface of the cone with the faint median ridge. The oblique broken base of this part fits onto the anterior end of Pl. 21, fig. 12, 13. The plan of the endosiphocone is shown in Text-fig. 11.

By the straight form and general organization of the endosiphocone, this siphuncle is consistent only with *Proterocameroceras*. Its small proportions, as well as the small median wedge on the venter, distinguish it from *P. brainerdi*, the only American species previously assigned to the genus.

The holotype, no. 42, is from the *Archeoscyphia* zone, 757′ above the base of the Rockdale Run formation of Sando's section 3.

Additional siphuncles, tentatively assigned to *Proterocameroceras*, but too poor for proper study, occur in Section 1 at 540′,

790′, and 856′, while at another locality loose blocks from a fence 0.85 miles N45E of St. Pauls Church, Md., occur at 435′. All of these forms are so incomplete that even the generic determination may require emendation. They appear, however, to have the pattern of *Proterocameroceras*, and cannot be assigned to the other genera recognized in the Maryland Canadian.

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EXPLANATION OF PLATE 21

FIG. *1, 2, 5–7*—*Mcqueenoceras cariniferum*, n. sp. 1, Dorsal view and *2*, lateral view, dorsum on left, paratype, no. 33. *5*, Lateral view, venter on left, *6*, Dorsal view of holotype, no. 34. 7, Dorsal view of paratype, no. 35. All ×2. *Archeoscyphia* zone. (p. 93)

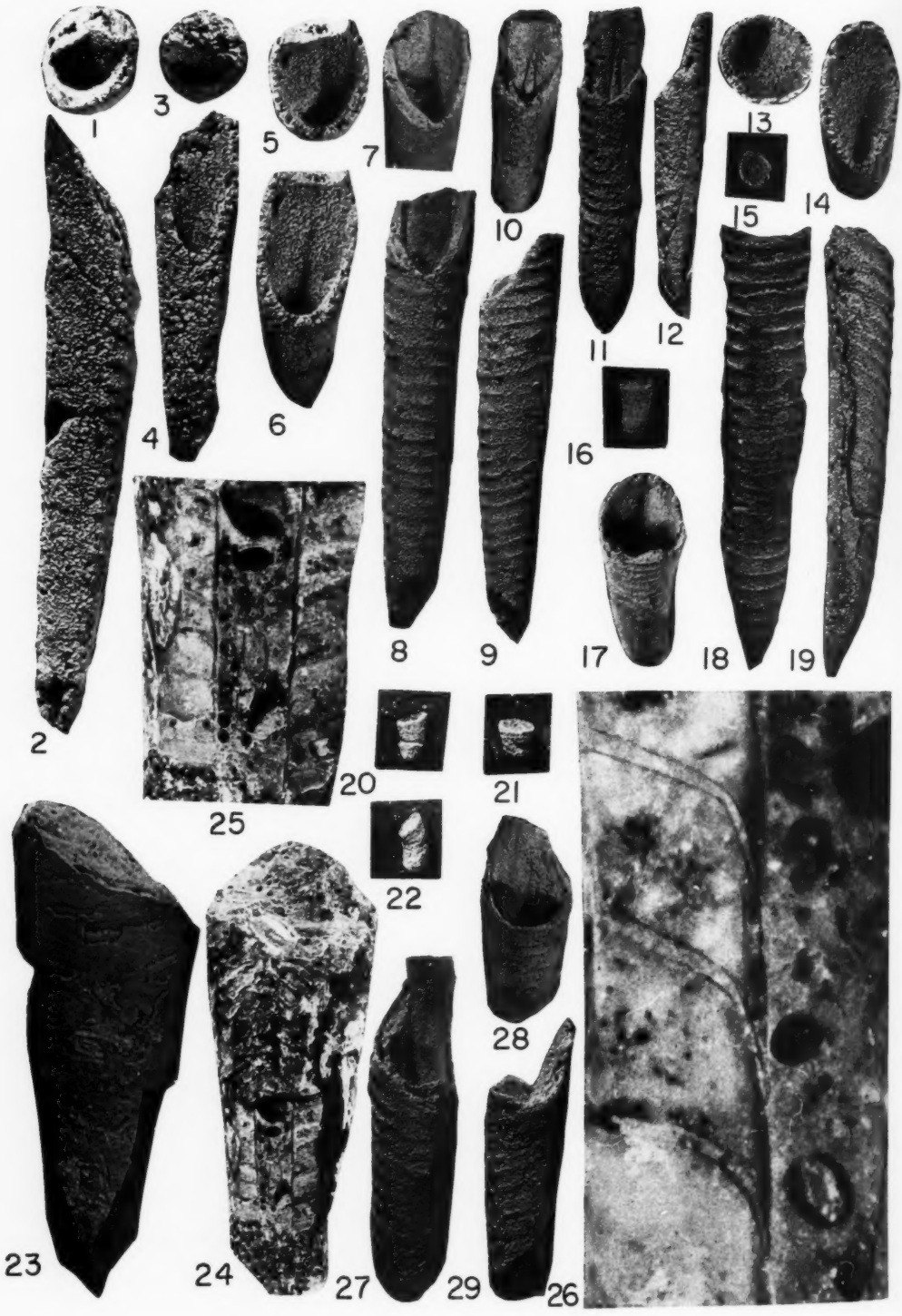
3, 4, 8, 9, 14–16, 21—*Mcqueenoceras ventrale* Flower, n. sp. *3*, Dorsal view, *4*, lateral view, venter on right, of holotype, no. 37. *8*, Dorsal and *9*, lateral view, venter on right, of fragmentary paratype, no. 39. *14*, Lateral view, venter on left, *15*, dorsal view, *16*, adoral view, dorsum with tip of cone below, of paratype, no. 39. All ×2. *21*, Ventral view, ×1.7. *Archeoscyphia* zone. (p. 94)

10–13—*Proterocameroceras normale*, n. sp. Holotype, ×2. *10*, Interior and *11*, lateral view of portion from adoral part of ventral side. *12*, Ventral and *13*, lateral view, venter on left, of remainder of specimen. *10*, and *11* fit on the anterior end. No. 42. *Archeoscyphia* zone. (p. 95)

17–20—*Clitendoceras subgracile*, n. sp. Holotype, ×2. *17*, Ventral view, *18*, lateral view, venter on left, *19*, dorsal view, *20*, adoral view, dorsum beneath. No. 24. *Archeoscyphia* zone. (p. 89)

22–28—*Platysiphon gracile*, n. sp. *22, 23*, Lateral and ventral views of paratype. *24–25*, Lateral and ventral views of second paratype, showing variation in conformation of early portions. *26*, Dorsal view, *27*, lateral view, dorsum on left, *28*, ventral view of holotype, all ×2. *Archeoscyphia* zone. (p. 84)

Flower, Canadian cephalopods, Maryland



Flower, Canadian cephalopods, Maryland

Flower, Canadian endoceroids, Texas

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SOME ENDOCEROIDS FROM THE EL PASO LIMESTONE

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ABSTRACT—Some small endoceroids, known only from silicified siphuncles, and exhibiting some remarkable structures, are described from the El Paso group. They comprise *Mcqueenoceras aculiferum, M. mediale, M. triangulatum* and *Clitendoceras breviconiferum*, all new species. All are from the lowermost Jefferson City beds of the Franklin Mountains at El Paso, Texas.

INTRODUCTION

As NOTED in the preceding paper dealing with cephalopods from the Canadian of Washington County, Maryland, the silicified endoceroid siphuncles are found to present valuable criteria for genera and species which have considerable faunal and stratigraphic significance. In the following pages are described a few analogous and related forms from the El Paso limestone of New Mexico and western Texas. The El Paso limestone, properly raised to group status, contains a series of beds ranging from equivalents of the Gasconade, lower Canadian, through a succession of beds ranging through equivalents of the middle and upper Canadian. The limestones are dense, fine grained, and only under exceptional conditions can other than the silicified fossils be removed in a condition proper for study. Though rich in representatives of many fossil groups, the greater number are unsilicified and almost defy extraction. Exceptions are the sponges, as yet not sufficiently worked for their faunal and stratigraphic value to be determined, and a prolific as-

EXPLANATION OF PLATE 22

Cephalopods from the Canadian of Maryland

FIG. *1, 2—Mcqueenoceras cariniferum*, n. sp. Holotype, *1*, adoral view, slightly oblique, from dorsal side. *2*, Ventral view. ×2. No. 34. (p. 93)

3, 4—Mcqueenoceras ventrale, n. sp. Paratype. *3*, Adoral view, venter beneath. *4*, Dorsal view, showing interior of tongue of endocones. ×2. No. 38. *Archeoscyphia* zone. (p. 94)

5, 6—Mcqueenoceras cariniferum, n. sp. Two oblique views from the dorsal side, showing groove in tongue and dorsal position of tube. No. 33. ×2. (p. 93)

13, 14—Mcqueenoceras ventrale, n. sp. *13*, Adoral view, dorsum above. *14*, Oblique view from dorsal side, showing surface of interior of endocone; both ×2. No. 37. (p. 94)

15, 16, 20–22—Dakeoceras? sp. Isolated silicified positions of siphuncle retaining diaphragms. *15*, Adoral view, *16*, lateral view, of fragments bounded anteriorly by diaphragms. *20*, Lateral view of fragment bounded on both ends by diaphragms, and cut in middle by a third. *21*, Ventral view of another fragment showing a diaphragm surface at either end. *22*, Exceptionally long slender specimen bounded by diaphragms. All ×2. (p. 79)

23–26—Ellesmeroceras (*Metaellesmeroceras*) *anomalum*, n. sp. Holotype, *23*, Lateral view, venter on right; whitened specimen; *24*, ventral view, natural color, both about ×2. Further enlargement of sectioned portion of venter, ×3. *26*, Portion of section, ×14, details of siphuncle wall faintly retouched. Stonehenge limestone. (p. 79)

(All from no. 1, Stonehenge formation)

Some endoceroids from the El Paso limestone

7–9—Mcqueenoceras triangulatum, n. sp. Holotype, *7*, Oblique adoral view, from dorsal side, *8*, dorsal view, *9*, lateral view, dorsum on left. (p. 99)

10–12—Mcqueenoceras aculiferum, n. sp. Holotype. *10*, Oblique adoral view from dorsal side, showing ventral side of cone. *11*, Dorsal view, *12*, lateral view, dorsum on left. (p. 98)

17–19—Clitendoceras breviconiferum, n. sp. *17*, Oblique anterodorsal view, *18*, dorsum, *19*, lateral view, dorsum to right. (p. 100)

27–29—Mcqueenoceras mediale, n. sp. Holotype. *27*, Dorsal view, *28*, oblique adoral view from dorsal side, ventral tongue a little left of center, *29*, lateral view. All ×2. (p. 99)

(All from the basal Jefferson City equivalent of the El Paso limestone)

semblage of cephalopods. In the following pages are described a few cephalopod types, published at this time largely because of their similarity to the forms described in the preceding paper. The forms described below are all from bed 17 of Cloud & Barnes (1948) of the type section of the El Paso limestone, at the southern end of the Franklin Mountains. This horizon was interpreted by these authors as equivalent to the basal Jefferson City beds of the Ozark region and the basal Honeycut beds of the Llano uplift. With this interpretation I would fully concur. Elsewhere (Flower, 1953, 1953a) a brief outline of the section of the Franklin Mountains has been presented, and also a summary of the stratigraphic succession of the El Paso limestone in New Mexico. The New Mexico sections differ materially from the type section at El Paso in several respects. Erosion prior to the inception of Montoya deposition, which certainly began as early as the Covington interval, and may even prove to be as old as middle Trenton, has clearly removed the higher part of the El Paso group in most of New Mexico. The New Mexico sections differ further in that there is a marked decrease in sand, which characterizes horizons in the section at El Paso, and dolomitization is less marked, and indeed, often absent.

It may be noted that, as might be expected from our knowledge of the Canadian faunal successions in other parts of North America, the El Paso group contains no one fauna. The lower beds, of Gasconade age, probably have no single species in common with those of middle or upper Canadian age. The equivalents of the Gorman formation of central Texas are thick, and have yielded two very distinct faunas, characterized very largely by the cephalopods and sponges. Above them is a fauna preserved in a dark oolitic limestone, which is unlike anything known either from central Texas or from Utah, characterized by small gastropods, trilobites, and cephalopods. Whether these beds are to be classed with the middle or upper Canadian is not yet evident. They occur below the sand marking the obvious base of the upper Canadian strata in the Franklin Mountains, but the oolitic nature of the beds, and most of the fauna as well, have been obscured by dolomitization. The succeeding thick limestones of the El Paso section have not yet been adequately differentiated, but it is probable that these beds, units 16 to 11 of Cloud & Barnes, include equivalents of the Jefferson City, Cotter and Powell formations. The overlying beds contain faunal elements suggestive of Fort Cassin and Smithville faunas, (B2b of Cloud & Barnes) while the overlying thin beds of division C, have been correlated with the Black Rock and Odenville formations by Cloud & Barnes. Equivalents of these two upper units have not yet been found in the New Mexico sections thus far examined in detail. Strong faunal similarities with the Manitou formation of Colorado suggest that it and the El Paso formations were once continuous. Their present wide geographic separation are due to arching and erosion, in part Middle Ordovician in age, but more largely by late Paleozoic, and probably pre-Pennsylvanian deformation and elevation.

No discussions of genera are included in the following descriptions. These generic groups have been dealt with previously (Flower, 1955, and in the paper preceding this one) and repetition would be pointless. The El Paso faunas contain a large association of Proterocameroceratidae and Piloceratidae, the description of which is now largely in its early stages.

SYSTEMATIC PALEONTOLOGY

MCQUEENOCERAS ACULIFERUM, n. sp.

Pl. 22, fig. 10–12

This species is based upon a silicified siphuncle, slender, small, straight. The holotype is 27 mm. long, extending from the apex to beyond the base of the endosiphocone, the anterior part of the ventral tongue of the endocone material being lost. The apex is bluntly expanded, the ventral profile straight, the dorsal profile convex. It increases from a blunt point to 3.2 and 4 mm. in the basal 4 mm. Thereafter the siphuncle is extremely slender, increasing to 4.4 and 5.4 mm. in the next 16 mm., which is as far forward as the dorsum is complete. Septal markings are close, 11 in 10 mm., the obliquity such that a transverse section may cut three of them, traversing two complete interspaces.

The endosiphocone is terminated in a

cone 0.6 mm. from the dorsum. The dorsal wall of endocone material is short, incomplete in the type but quite clearly not over 4 mm. in length. The ventral side is bounded by a transverse tongue-like process of endocone material. In its present incomplete condition it extends 9 mm. forward from the tip of the cone, and when complete was between 12 and 15 mm. in length. Anteriorly, the inner dorsal surface of this process is flattened, with a broad shallow median groove. In the basal part the groove is modified by, and largely replaced by a prominent narrow elevated median ridge, pointed in front, and resembling the point of a needle, broad basally, narrowing anteriorly to a sharp point.

Discussion.—The slender form, closely spaced and strongly oblique septal markings, and the remarkable configuration of the ventral side of the endosiphocone characterize this species. Though the siphuncle is straight, the endocone configuration clearly indicates its affinities with *Mcqueenoceras.*

Type and occurrence.—The holotype, in the collection of the New Mexico Bureau of Mines, is from the basal dolomites of Honeycut age, lower Jefferson City equivalent, from the upper cherty portion of unit 17 of Cloud & Barnes (1948, p. 366).

MCQUEENOCERAS MEDIALE, n. sp.
Pl. 22, fig. 27–29

This species is based upon a siphuncle, agreeing closely with the preceding form in the ventral surface of the cone, but differing in a more depressed cross section, less oblique septal markings, and in showing very slight endogastric curvature. The type, showing the anterior end of an endosiphocone, is very slightly curved, increasing from 5 and 6 mm. to 6 and 7 mm. in a length of 15 mm. The specimen is 35 mm. in length. Seven septal markings occur in a length of 10 mm., their obliquity is less than in *M. aculiferum*, so that a transverse section will traverse only one complete interspace.

The cone terminates in a tube 1.6 mm. from the dorsum where the siphuncle is 6.8 mm. high. The endocone material terminates dorsally 4 mm. in front of the tip of the cone. The ventral wall is incomplete at a length of 13 mm. The inner surface of the ventral tongue is flatter than in the preceding form, bears anteriorly a faint median groove, narrower, shallower and more strongly incised than that of the preceding species. Near the base of the cone there is a median ridge, pointed in front, narrower and less strongly elevated than in the preceding species.

Discussion.—The proportions, as noted, indicate that this form is specifically distinct from *M. aculiferum*, the siphuncle being slightly curved, more rapidly expanding, the septal markings less oblique, the cross section more depressed, and the pattern of the cone being somewhat different. Variations are of such a nature that they cannot be explained as those to be expected in a later growth stage.

The holotype, in the New Mexico Bureau of Mines, is from unit 17 of Cloud & Barnes (1948, p. 366) from dolomites of basal Honeycut, lowermost Jefferson City age, from the southern end of the Franklin Mountains on the edge of El Paso, Texas.

MCQUEENOCERAS TRIANGULATUM, n. sp.
Pl. 22, fig. 7–9

Holotype a siphuncle 36 mm. in length. Ventral profile straight, dorsum convex apically, straight adorally. Siphuncle expanding from 4 and 4.5 mm. to 6.5 and 6.7 mm. in 24 mm., beyond which the dorsum is incomplete. Septal markings moderately oblique, nine in 10 mm. apically, eight in 10 mm. adorally. Obliquity is such that a transverse section crosses one and a half interspaces.

The cone terminates twice as far from the venter as from the dorsum. The ventral endocone material is prolonged forward in a tongue, its inner surface slightly convex, separated by sharp angles from the sides. The walls are thickened dorso-laterally, thinning rapidly toward the middorsal region, so that the cavity near the apex is strongly triangular.

Discussion.—Not only does this siphuncle differ from associated forms in external proportions, but the triangular section near the apex of the cone is distinctive. In some respects this species approaches the features of both *Clitendoceras* and *Proterocameroceras*, but the prominent ventral

tongue and the dorsal position of the tube indicate that it is closer to other species of *Mcqueenoceras*.

Type and occurrence.—The holotype is in the collection of the New Mexico Bureau of Mines. It is from the same locality and horizon as the preceding forms, the basal Honeycut horizon, bed 17 of Cloud & Barnes, from the southern end of the Franklin Mountains on the edge of El Paso.

CLITENDOCERAS BREVICONIFERUM, n. sp.
Pl. 22, fig. 17–19

The holotype is a small siphuncle 33 mm. long, retaining the apex and extending to the tip of the endosiphuncle. The ventral profile is faintly concave anteriorly, straight near the apex, and the extreme apical end faintly convex. The dorsal profile is slightly convex throughout, and strongly so near the apex. The siphuncle expands in the basal 5 mm. to 3.5 and 4 mm., being faintly depressed in section, and in the remaining 28 mm. to 6.5 and 7 mm. Septa are nearly uniform in spacing, eight and a half in 10 mm. apically, eight in 10 mm. adorally. Obliquity of the septal markings is slight, a horizontal line intersecting one and a third interspaces.

The endosiphocone terminates only very faintly dorsad of the cross section. Dorsally and laterally the walls are short, rather widely expanding, the cone having a depth of only 5 mm. Here the endocone material conforms closely to the cross section of the shell. On the venter, the material is thickened into a broad low wedge, its inner surface faintly convex, set off by sharp angles on the sides. This process is not extended far forward into a tongue as in typical *Mcqueenoceras*, but terminates little if any orad of the remainder of the endosiphuncle. Owing to its rapid thickening, this wedge would be seen to have a slightly convex form were it seen from a vertical section. No trace of blades or other internal structures are preserved. Sections through the cone would show it to be more than a semicircle except near its extreme apex, rather crescentic, the ventral side scarcely concave.

Holotype.—New Mexico Bureau of Mines.

Occurrence.—From bed 17 of the El Paso limestone at the southern end of the Franklin Mountains, basal Honeycut, i.e., basal Jefferson City in age.

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MANUSCRIPT RECEIVED MARCH 11, 1955

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 101–103, PL. 23, JANUARY 1956

AN *ENDOLOBUS* FROM THE BEAVER BEND LIMESTONE (CHESTER) OF INDIANA

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ABSTRACT—A large, well preserved representative of *Endolobus* is described from the Beaver Bend limestone (lower Chester) of Indiana. The Beaver Bend specimen appears to represent an undescribed species of the genus, for which the name *Endolobus indianensis*, n. sp., is herein proposed.

THE Beaver Bend limestone, which was named (Malott, 1919, p. 9–10) for an exposure in the bottom of a deep cut along the Baltimore and Ohio Railroad in southwestern Lawrence County, Indiana, is persistently present throughout the area of Chester outcrop in southwestern Indiana. It lies between the shales and friable sandstones of the Mooretown formation, and the massive cross-laminated beds of the Sample sandstone, and is now considered to be lower Chester in age (Weller, et al., 1948; Malott, 1952). According to Malott (1952, p. 13) the Beaver Bend ranges from a few feet to about 20 feet in thickness, but characteristically is only 10 to 14 feet thick. The formation consists of massive beds of granular to finely granular, creamy white, oolitic limestone, certain units of which are composed in large part of echinoderm and brachiopod fragments. The Beaver Bend limestone thins toward the eastern margin of Chester outcrop, and in western Putnam County, Indiana, it is cut out and overlapped by the Pennsylvanian Mansfield sandstone.

Locally, the Beaver Bend limestone contains an abundance of brachiopods, blastoids, echinoids, snails, and fragments of other fossil groups. However, insofar as we have been able to ascertain, not a single cephalopod has been described or illustrated from any of the strata now generally included in the formation. Therefore, the discovery of a well preserved coiled cephalopod in the Beaver Bend seems to merit special consideration.

The cephalopod to which we refer was collected by the junior author from the type locality of the Beaver Bend limestone, in a railroad cut half a mile east of the town of Huron, Lawrence County, Indiana. Although the specimen was found in several pieces, lying on the weathered surface of the Mooretown shales, its lithologic character indicates that it came from the immediately overlying Beaver Bend limestone, and almost certainly from the basal one foot of that formation.

There is no doubt but that this specimen belongs in Meek & Worthen's genus *Endolobus*, which was erected by them to include forms similar to ours collected from the Chester of Illinois. Miller & Youngquist (1949, p. 39–40) have recently given an extensive diagnosis of the genus. They point out that nautiloids properly referable to *Endolobus* are characterized by nautiliconic conchs which are not deeply involute, and which are subelliptical in cross section, being broadly rounded ventrally, rather narrowly rounded laterally, and slightly impressed dorsally. The umbilicus of typical forms is wide, deep, and presumably perforate, and the lateral zones of the whorls bear a series of more or less prominent nodes. The external sutures are only slightly sinuous, but each internal suture forms a rather prominent dorsal lobe. The siphuncle is small, subcentral, and orthochoanitic. As thus defined, *Endolobus* is known to have a widespread geographic distribution, and a stratigraphic range from the Middle Mississippian well into the Lower Permian. The specimen that we are studying, however, compares most favorably with the accepted type of the genus, *Endolobus spectabilis* (Meek & Worthen), from unidentified strata in the Chester of Illinois.

[1] Published with the permission of the State Geologist, Indiana Geological Survey.

SYSTEMATIC DESCRIPTION

ENDOLOBUS INDIANENSIS, n. sp.

Pl. 23, fig. 1, 2

The specimen that we are studying does not seem to be referable to any described species of *Endolobus*, hence we are proposing the name *Endolobus indianensis* for it. The conch is large, subglobular in shape, and consists of nearly two and a half volutions of the phragmocone. Its maximum diameter (measured across the whorls) is slightly more than 132 mm. The whorls are subreniform in transverse outline, being gently convex ventrally, narrowly rounded laterally, and broadly rounded dorsally. However, there is a rather wide impressed zone along the median portion of the dorsum, whose curvature in transverse section is nearly parallel to that of the venter. At the adoral end of the phragmocone, the conch is 81 mm. wide and 40 mm. high.

The umbilicus is large, its shoulders are quite distinct, and its diameter is slightly less than two-thirds that of the conch. Consequently, the lateral zones of all the inner volutions are clearly visible. There seems to be no question but that the umbilicus of our specimen is perforate, and that the diameter of the perforation is about 20 mm.

Coincident with the narrowly rounded lateral margins of the conch, there occurs a row of low, rounded nodes. Although these structures are most prominent on the lateral margins of the innermost volution, they are also discernible in comparable areas of the outer whorl. Fifteen nodes occur on the margins of the inner volution, and a similar number are estimated to be present on the outer whorl.

The camerae are relatively short, a few more than 20 occurring in the length of the first volution, and an estimated 27 occupying the length of the second whorl. The adoral 6 or 7 camerae are somewhat shorter than those immediately preceding them adapically, which may indicate that the conch represents that of a mature individual. The sutures form slight, broadly arched saddles in the median portion of the venter, and are rather markedly deflected orad in the lateral zones to form narrowly rounded saddles there. On the dorsum the sutures swing slightly apicad, being more strongly lobate across the impressed zone.

The siphuncle is not exposed at the adoral end of the specimen, but its position is revealed on the septal face of the eighth camera apicad of the adoral terminus. At that place it is circular in cross section, slightly less than 4 mm. in diameter, and subcentral in position.

Remarks.—Our specimen compares very closely with the only illustrated representative of *Endolobus spectabilis* (Meek & Worthen), the type species of the genus. Both have subcentral siphuncles, and the sutures of each form slight ventral saddles. Meek & Worthen's illustrations indicate, however, that *E. spectabilis* expands rather rapidly orad in the outer volution, whereas the lateral diameter of our specimen increases only slightly in a comparable portion of the conch. The camerae of *E. spectabilis* are apparently much longer than are those of the form we are studying, and, according to Meek and Worthen (1866, p. 308–309), their specimens reached over-all dimensions more than twice those of *E. indianensis*.

Endolobus indianensis is also similar to a form from the Chester of Greene County, Indiana, described as *Temnocheilus greenense* by Miller & Gurley (1897), and to the three specimens from the Greenbrier limestone of southwestern Pennsylvania which Miller & Collins (1947) made the types of *E. greenbrierensis*. All of these specimens, however, appear to be more narrowly rounded ventrally than the Beaver Bend form. Furthermore, the siphuncle of *E. greenbrierensis*

EXPLANATION OF PLATE 23

FIG. *1, 2*—*Endolobus indianensis*, n. sp. Ventral and lateral views of the holotype, ×1; from type locality of Beaver Bend limestone (Chester), NE ¼ SW ¼ sec. 5, T. 3 N., R. 2 W., Lawrence County, Indiana.

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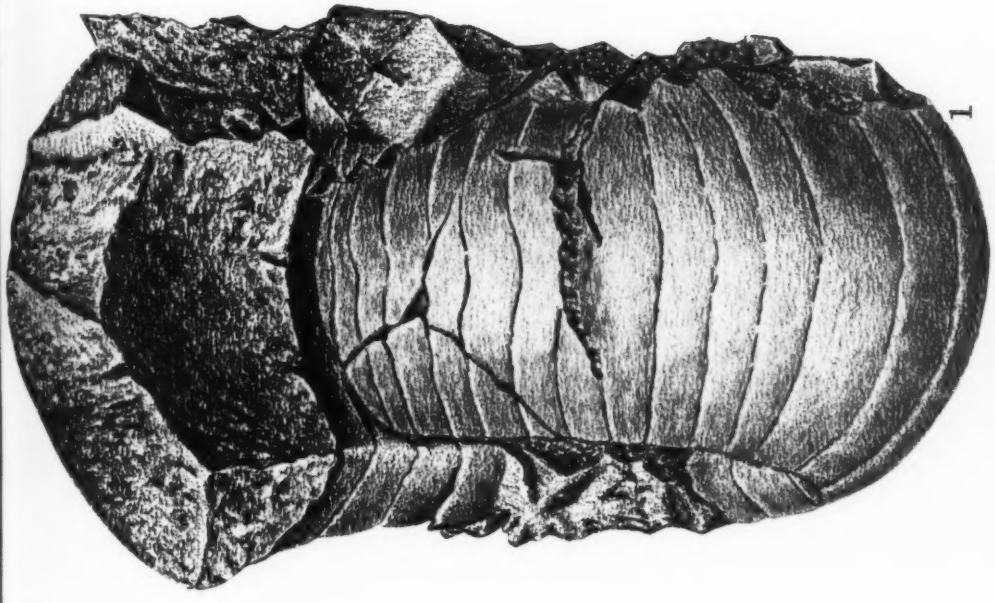

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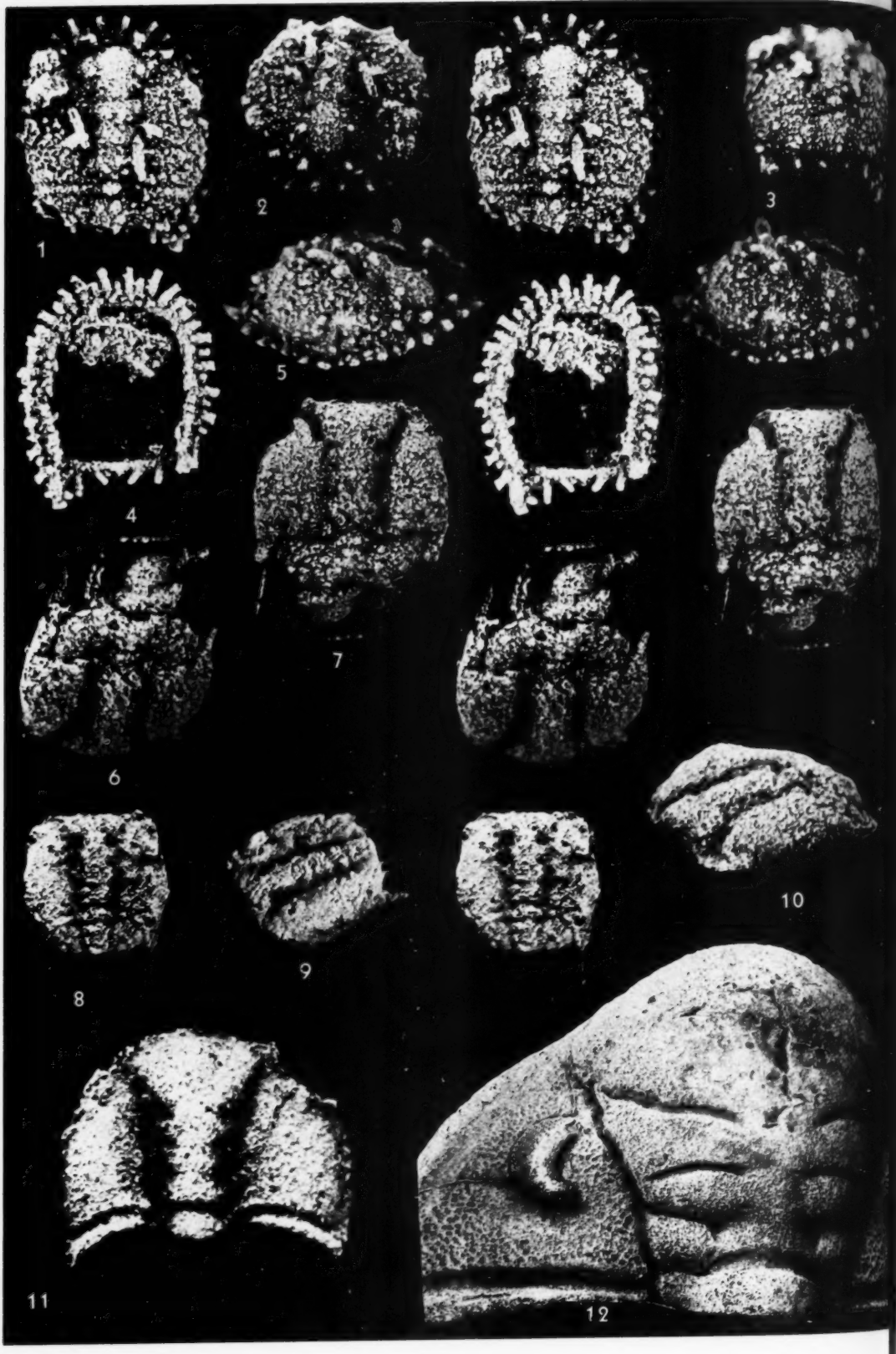
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Miller & Collins is distinctly subventral in position.

Endolobus clorensis, a large, long-chambered representative of the genus, recently described by Collinson (1955) from the Clore limestone of western Kentucky, has a subcentral siphuncle, and a cross sectional shape similar to that of the specimen at hand. However, the Clore limestone form has camerae which are considerably longer than those of *E. indianensis*.

Occurrence.—Type locality of Beaver Bend limestone, in Baltimore and Ohio Railroad cut, just south of U. S. Highway 50, NE¼ SW¼ sec. 5, T. 3 N., R. 2 W., one-half mile east of Huron, Lawrence County, Indiana.

Holotype.—Indiana University Paleontological Collections, Cat. No. 5555.

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MANUSCRIPT RECEIVED APRIL 30, 1955

EXPLANATION OF PLATE 24

FIGS. *1–5*—Phacopid metaprotaspis. *1*, *4*, *5*, Dorsal, ventral, anterolateral stereographs; *2*, *3*, anterodorsal, posterodorsal views. Original of Beecher, 1893, pl. 2, fig. 5–7. New Scotland limestone, Indian Ladder, Albany Co., N. Y. ×30. Peabody Mus., Yale Univ., no. 6614. (p. 105)

6–12—*Dalmanitina socialis* (Barrande, 1846). *6*, *7*, *10*, Metaprotaspis, posterodorsal stereograph showing hypostome and part of doublure, dorsal stereograph, left anterolateral view. Zahořany beds, Točnik, Bohemia. ×30. Mus. Comp. Zool. 5258. *8*, *9*, Metaprotaspis, dorsal stereograph and left anterolateral view. Zahořany Beds, Černin, Bohemia. ×30. Mus. Comp. Zool. 5259. *11*, Meraspid cranidium, dorsal view. Drábov quartzites, Mt. Drábov, Bohemia. ×30. Mus. Comp. Zool. 5260. *12*, Holaspid cephalon, oblique dorsal view. Drábov quartzites, Mt. Drábov, Bohemia. ×3. Mus. Comp. Zool. 5261.

Right hand figure of pair forming a stereograph not numbered. (p. 106)

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 104–109, PL. 24, 2 TEXT-FIG., JANUARY 1956

BEECHER'S SUPPOSED ODONTOPLEURID PROTASPIS IS A PHACOPID

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ABSTRACT—The Lower Devonian metaprotaspis described in 1893 by Beecher as that of *"Acidaspis" tuberculatus* is redescribed. Comparison with metaprotaspides of the Ordovician species *Dalmanitina socialis* Barrande and *D. olini* Temple shows that Beecher's specimens are most probably of a phacopid protaspis. Acceptance of this view has led to a new reconstruction of the *Dalmanitina* metaprotaspis, and shows that the "preantennal segment complex" is represented on the dorsal side of the exoskeleton. Evidence is given against the suggestion of Temple that the anterior glabellar furrow is a composite structure.

INTRODUCTION

IN 1893 Beecher described two trilobite protaspides from the Lower Devonian of New York State. One of these he referred "without hesitation" to the odontopleurid species *"Acidaspis" tuberculatus* Conrad, 1840, "since it retains one of the most characteristic features, viz: the denticulate cephalic border." Through the kindness of Dr. Karl M. Waagé, Peabody Museum, Yale University, I have had the opportunity to examine these specimens, and one is redescribed below. As may be seen from the photographs (Pl. 24, fig. 1–5) it is a metaprotaspis, the glabella divided into a short (sag.) occipital ring, in front of which are three longer rings about equal in size, and a longer (sag.), wider, frontal lobe; the cheek is wide, convex, with a long, steeply sloping lateral area, and backwardly directed fixigenal spine, the eye lobe is situated well forward and outward, the free cheek small, triangular, the suture proparian, the anterior branches confluent along the margin of the narrow (sag. and exs.) anterior border, the protopygidium small, steeply sloping, with a clearly defined axis. These characters are displayed by metaprotaspides of *Dalmanitina socialis* described here (Pl. 24, fig. 6–10), and by similar material of *D. olini* recently described by Temple (1952). The free cheeks and anterior doublure are not retained in place in these European specimens, which are preserved in shale and consequently flattened. This incompleteness and flattening means that the row of spines around the cephalic margin, so characteristic of Beecher's specimens, is, if present, missing anteriorly and concealed laterally. One specimen of *D. socialis* has part of the anterior doublure, bearing a row of high tubercles, and with the hypostome attached, preserved but displaced (Pl. 24, fig. 6). Silicified phacopid protaspides from the Middle Ordovician of Virginia, in collections made by W. R. Evitt and me, show the spines around the cephalic margin, and suggest that such spines are typical of phacopid protaspides. Further, silicified odontopleurid protaspides in our collections are quite different from either Beecher's specimens or those of *Dalmanitina*. Therefore I conclude that the specimens Beecher described as *"A. tuberculatus"* are phacopid, not odontopleurid, protaspides.

While acceptance of this conclusion implies that the protaspis of an odontopleurid trilobite is so far undescribed, it means also that Beecher's specimens are the best preserved phacopid protaspides so far described. Interpretation of *Dalmanitina* in this light provides a new reconstruction of the metaprotaspis (Text-fig. 2) showing the glabellar furrows, small free cheeks, anterior border, and position of the doublure and hypostome. The view of Størmer (1942) and Hupé (1954) that the "preantennal segment complex" is not represented on the dorsal side of the phacopid protaspis thus seems to be erroneous, and the suggestion of Temple (1952) that the anterior glabellar furrow in *Dalmanitina* is a composite structure is not upheld.

In the descriptions I have used the same terminology as previously (Whittington &

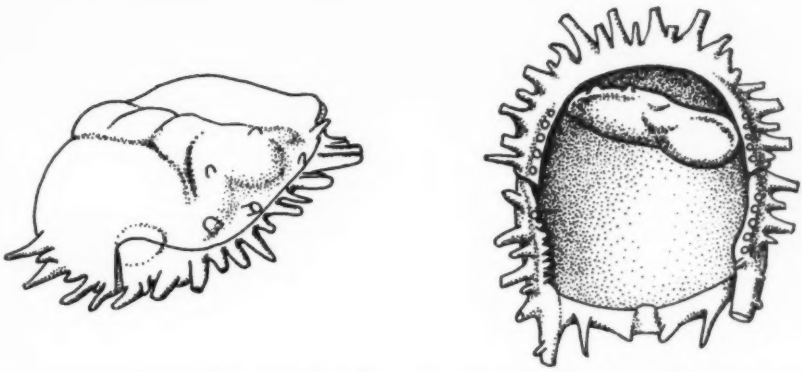

FIG. 1—Phacopid metaprotaspis, original of Beecher, 1893, pl. 2, fig. 5–7, anterolateral (left) and ventral views (compare Pl. 24, fig. 5 and 4, respectively). Approx. ×38.

Evitt, 1954), and in particular have included the occipital ring as part of the glabella.

SYSTEMATIC DESCRIPTIONS

Family PHACOPIDAE Hawle & Corda, 1847

Phacopid protaspis

Pl. 24, fig. 1–5; Text-fig. 1

Acidaspis tuberculatus BEECHER, 1893, p. 144, Pl. 2, fig. 5, 6, 7.

Material, geological horizon and locality.—One complete silicified specimen, original of Beecher's figures, and basis of present redescription, and a second incomplete specimen (a third was accidentally destroyed), Peabody Museum, Yale University, no. 6614, from the Lower Devonian, New Scotland formation, Indian Ladder, Albany Co., N.Y. Beecher (1893, p. 142) gave no precise locality, referring only to "a limited locality in the Helderberg Mountains, south of Albany, New York." Ruedemann (1930, pp. 49–50) drew attention to the abundance of fossils in these beds, and to the active collecting in this area in the early days.

Description.—Shield subcircular in outline, length (sag.) 1.08 mm., maximum width 1.02 mm., length (exs.) including spines about 1.4 mm., strongly convex with lateral and posterior slopes vertical. Glabella (Pl. 24, fig. 1, 2, 5) 0.8 m. long, convex, standing above remainder of shield, axial furrow broad and shallow beside occipital ring and first three lateral lobes, then curving outward and becoming vaguely defined beside frontal glabellar lobe. Occipital ring short (sag.), low, prominent median tubercle; occipital furrow shallow medially, distally expanding and deepening into a subcircular pit. In front of occipital ring glabella divided into three higher, longer (sag.), subequal rings; transverse furrow defining each ring extremely shallow medially, becoming a subcircular pit distally, these appendiferal pits situated immediately inside the axial furrow. Frontal glabellar lobe subcircular in outline, wider than first three rings and about twice as long (sag.); faint depression, roughly in line with posterior part of axial furrow, runs backward from anterior margin and ends at short spine situated just inside posterolateral margin of frontal lobe. Anterior border flat, short (sag. and exs.), separated by change of slope, not a furrow, from glabella, and continuous with fixed cheeks which descend vertically laterally and are bounded posteriorly by the low, narrow (exs.) posterior border. This border proximally in line with occipital ring, distally curving back and merging with base of backwardly directed fixigenal spine. Eye lobe situated on anterolateral slope of cheek, opposite most posterior part of frontal glabellar lobe. Left eye lobe concealed by fragments adhering to specimen, but right is subcircular in outline, convex, divided unequally by outward-curving suture so that palpebral lobe is larger part. Coarse granularity of silicification has obliterated any facets that may have been preserved on eye surface. Tiny free cheek triangular, anterior branch of suture running

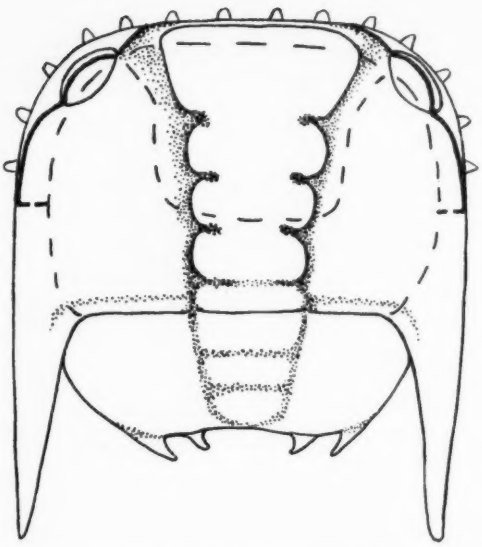

FIG. 2.—Metaprotaspis of *Dalmanitina socialis*, dorsal view, based on original of Pl. 24, fig. 6, 7, 10. Dotted line indicates inner margin of doublure, outline of hypostome, and posterior branch of suture crossing doublure. Approx. ×60.

downward and forward to margin, then along anterior margin between row of horizontally projecting border spines and pairs of spines on preglabellar field (Pl. 24, fig. 2, 5; Text-fig. 1). Thus the two free cheeks are joined by a narrow strip of anterior doublure, which bears horizontally directed border spines. Posterior branch of suture curves downward and backward to lateral margin at about half length of shield, then runs between border spines and across doublure (Pl. 24, fig. 4; Text-fig. 1). Doublure narrow, extending around cephalic part of shield between bases of fixigenal spines, at outer margin a row of horizontally directed spines, alternately long and short (except that there is no short spine between the second and third long spines, counting from the anterior midline), 10 long ones on each side between midline and base of fixigenal spine, a short spine at anterior midline. Two pairs of spines on anterior margin conspicuous and longer than others. On inner side of lateral doublure a row of tiny spines.

Protopygidium (Pl. 24, fig. 3, 4) small, length (sag.) 0.2 mm., maximum width 0.76 mm., sloping steeply posteriorly to margin, which is curled under but not extended inward. Axis convex, defined by deep furrow separating it from occipital ring and faint axial furrows, extending to posterior margin, not divided into rings. Some suggestion of a division into two or three segments in inner part of right pleural region and two pairs of border spines, outer backwardly directed, inner convergent.

External surface of protaspis granulate, except in furrows. Paired spine on frontal glabellar lobe, anterior border at anterolateral corner of glabella, at anterior margin of fixed cheek, on fixed cheek just in front of posterior border furrow and short way out from axial furrow, at base fixigenal spine, and at base anterior border spine of protopygidium. Coarse granularity of quartz and fragments adhering to surface may conceal other spines and details of external surface.

As the ventral view shows (Pl. 24, fig. 4; Text-fig. 1), there is a plate lying inside the anterior part of the cavity formed by the protaspis, but there are also many sedimentary particles in the cavity and on and about this plate. Thus its form is obscured, but the margin on the anterior-facing side is straight, the others curved; it is convex, and divided into two subequal lobes with a small median swelling. There appear to be some spines on the surface. Its position is suggestive of its being the slightly displaced hypostome, but the shape is not typically phacopid, as is that of *Dalmanitina socialis* (Pl. 24, fig. 6). I am inclined to think it is not the hypostome, but perhaps an immature ostracod carapace.

Discussion.—The New Scotland formation of New York State, from which Beecher obtained his specimens, has yielded species belonging to five different genera of phacopids, as well as two genera of odontopleurids, a lichid and a homalonotid. Without more information on the ontogeny of the phacopids I am unable to decide to which genus the specimens belong.

DALMANITINA SOCIALIS (Barrande, 1846)
Pl. 24, fig. 6–12; Text-fig. 2

Dalmania socialis BARRANDE, 1852, p. 552–556, pl. 21, fig. 32; pl. 22, fig. 3–8; pl. 26, fig. 1–25; pl. 27, fig. 15–17.

Discussion.—Metaprotaspides of this species in the Schary Collection, Museum of Comparative Zoology, preserved as internal

molds, include no. 5257, four specimens labelled by Barrande, from dark micaceous shale, lower Zahořany beds (Dd_3 of the old terminology), Trubin, Bohemia; no. 5258, two specimens from a similar lithology and horizon at Točnik, and no. 5259, a specimen from Černin, Bohemia. Five are 0.8 to 0.85 mm. in length (sag.), including the original of Pl. 24, fig. 8, 9, one (original of Pl. 24, fig. 6, 7, 10) is 0.97 mm. in length (sag.), and the largest 1.18 mm. Up to three pairs of border spines are preserved on the protopygidium of the largest specimen, and it is thus like Barrande's (1852) pl. 26, fig. 3, the smallest being like fig. 1. Cephalic portion with well-defined, convex glabella reaching forward almost to anterior margin, transverse furrows, faint medially but deepening distally to end just inside the axial furrows in shallow pits, divide the glabella into five rings: a short (sag.), narrow occipital ring, 3 rings in front of this of about equal length (sag.) but becoming progressively very slightly wider anteriorly, and the frontal lobe the longest, widest, and most convex. Outside the deep axial furrows the wide cheeks are convex, the long lateral parts descending vertically to the border, which is extended into the posteriorly directed fixigenal spines. A narrow (exs.) convex posterior border, proximally in line with the occipital ring, curves outward and backward to merge with the base of the fixigenal spine. Palpebral lobe situated on outer slope of cheek opposite posterior part of frontal glabellar lobe. Anterior branch of suture curves forward and inward and runs along margin to midline, the paired branches forming a smooth curve which defines the anterior border. Latter exceedingly short (sag. and exs.), especially medially, and separated from the frontal lobe by a change in slope rather than a furrow. Posterior branch of suture curves outward and slightly backward to lateral margin (Pl. 24, fig. 10). Eye surface and triangular free cheek missing in all specimens.

In one specimen (Pl. 24, fig. 6, 7; length (sag.) 0.97 mm., maximum width 1.08 mm.) the hypostome and part of the doublure are preserved immediately behind the protopygidium, the outer (ventral) surface facing backward and upward (i.e. the hypostome and doublure have been rotated through an angle of about 100° relative to the cranidium and protopygidium). The hypostome is shield shaped, of length (sag.) about 0.35 mm., convex middle body divided into large anterior and small crescentic posterior lobes, posterolateral border broad. Anterior wings large, triangular. Anterolateral doublure a narrow strip, bearing a close-spaced row of high tubercles. The relative positions of the dorsal shield of the metaprotaspis (cranidium and protopygidium) and the rostrum and hypostome are the same as those of the cranidium and fused rostrum and hypostome of *Paedeumias yorkense* figured by Walcott (1910, pl. 34, fig. 6; refigured Resser and Howell, 1938, pl. 9, fig. 6). Hupé (1953a, p. 120–122, text-fig. 18) has claimed that this specimen of *P. yorkense* represents a molted exoskeleton, and that of *D. socialis* may equally well represent such a molt. The other metaprotaspides of *D. socialis* in the Schary Collection lack the free cheeks (and presumably also the hypostome and doublure), and seem therefore to represent only the dorsal portions of molts. The absence of the free cheeks and anterior portion of the doublure joining them, combined with flattening of the specimens in the shale, almost obscures the narrow anterior border.

DISCUSSION

Temple (1952) described the ontogeny of *Dalmanitina olini*, and the best preserved metaprotaspis (Temple, 1952, pl. 9, fig. 3; pl. 10, fig. 6) is smaller than Beecher's specimen, but shows the same general features. There are differences in detail—of ornament, convexity etc., and the anterior pit, which is clearly visible in *D. olini*, is absent in the American phacopid. There is, however, a counterpart of the "oval area" . . . "cut off on each side of the frontal lobe" (Temple, 1952, p. 254), and of the indentation in the anterior margin of the frontal lobe by the furrow marking off this area. In the American phacopid this area (Pl. 24, fig. 1, 2, 5) is less clearly cut off, and the longitudinal furrow does not extend back all the way to the third glabellar furrow. In the protaspis of *D. socialis* (Pl. 24, fig. 7–10; original of fig. 8 smaller than the original of Temple's pl. 9, fig. 3, original of fig. 7 about the same size) no anterior pit is visible in the broad, shallow axial furrow, and the frontal glabellar lobe appears undivided.

Temple (1952, p. 255–259) has also claimed that in the early meraspid stages of development of *D. olini* the third lateral glabellar lobe becomes enlarged by merging with the adjacent part of the cheek so that the axial furrow is deflected outward. At the same time the third lateral glabellar furrow merges with part of the former axial furrow, and thus has a twofold origin, so that it curves forward distally and terminates at the anterior pit. In the protaspis described by Beecher the axial furrows become vaguely defined in front of the third glabellar ring, there is no anterior pit, and one cannot say precisely where glabella ends and cheek begins. Thus, in terms of Temple's (1952) Text-fig. 1, the glabella has the approximate outline a h c d e d′ c′ h′ a′, rather than a h b d e d′ b′ h′ a′, i.e. the deep, outer parts of the second and third glabellar furrows are situated a short distance within the axial furrows. In this event it would seem that the later development of the third glabellar furrow would not involve a twofold origin. In the protaspis of *D. socialis*, as in that of *D. olini*, axial furrows are well-marked, deep troughs. These specimens are all preserved as internal molds, in fine-grained clastic sediments, and have been somewhat distorted and probably flattened. It is possible, if not probable, that the flattening has, by pressing the axial region down between the pleural regions, emphasized the strength of the axial furrows, and may have made their course appear more definite than in fact it was. There are no anterior pits in the metaprotaspis of *D. socialis*, but the second, and notably the third, pair of pits forming the lateral glabellar furrows are situated a short distance inside the axial furrows (Pl. 24, fig. 7, 8; Text-fig. 2). Thus the glabella has rather the outline a h c d e d′ c′ h′ a′ (in terms of Temple, 1952, Text-fig. 1), and comparison with a meraspid cranidium (Pl. 24, fig. 11; length (sag.) 1.1 mm.) suggests that later lengthening of the third glabellar furrow is by its extension outward, without involvement of other furrows. An internal mold of the holaspis of *D. socialis* (Pl. 24, fig. 12) shows the persistence of the early characters—the deep appendifers of the occipital and first glabellar furrows close to the axial furrow, the shallower second and third glabellar furrows, deepest at the inner end and dying out before reaching the axial furrow. An extremely shallow anterior pit is present, opposite the outer end of the third glabellar furrow.

Text-fig. 2 represents diagramatically the protaspis of *Dalmanitina socialis*. The inner edge of the doublure and the outline of the hypostome are shown by the broken line, as also is the probable course of the posterior branch of the suture across the doublure. The exact number, distribution and size of the short spines on the cephalic margin is not known, so that some only are shown. This restoration has been made in the light of the silicified specimen of Beecher, which, though of Lower Devonian rather than Ordovician age, seems to be extremely similar. Silicified Ordovician phacopid protaspides in collections made by W. R. Evitt and me also support this reconstruction. The most important difference from earlier figures is the representation of a narrow anterior border and free cheeks. The specimens show how the frontal glabellar lobe slopes steeply down to the horizontal anterior border (as was shown by Temple to be the case in *D. olini*), and that the fused anterior branches of the suture run along the margin. They also reveal that the eye lobes were not marginal, but situated a short distance up the antero-lateral slope of the cheek, and that a narrow free cheek, foreshortened in Text-fig. 2, was present on the dorsal surface. Thus the oft-repeated statement (e.g. Beecher, 1895, p. 174; Størmer, 1942, p. 72, 135–136; Hupé, 1953b, p. 96, 106) that the eye lobes in phacopid metaprotaspides are marginal is not correct, and such drawings as those of Barrande (1852, pl. 26, figs. 1, 2). Størmer (1942, pl. 1, fig. 36–38), and Temple (1952, pl. 9, fig. 1–3; pl. 10, fig. 6) are misleading in that they portray specimens which have been flattened in shale, and from which the free cheeks and doublure are probably missing (cf. Pl. 24, fig. 7, 8). Therefore, Størmer's (1942) discussion of the "preantennal segment complex" in proparian trilobites, based mainly on such drawings, seems to me to be erroneous. The "preantennal segment complex" is said to include the doublure, preglabellar field and free cheeks, probably the anterior part of the frontal glabellar lobe, and possibly also the hypostome (Størmer, 1942, p. 123) and to be "not at all present on the dorsal side of the protas-

pis" (Størmer, 1942, p. 156) in proparian trilobites. The diagrams illustrating this thesis are based on *Dalmanitina* (Størmer, 1942, Text-fig. 19, p, q, r). Apparently the shading in figures 19q and 19r indicates the position of the doublure of the free cheeks, as well as that part of the frontal glabellar lobe included in the "segment complex." A similar shading should be present in Text-fig. 19p, though not perhaps extending as far posterolaterally. It need hardly be added that with this change the "arrested development" of the "preantennal segment complex" claimed to be shown by proparian trilobites (Størmer, 1942, p. 156) becomes hardly at all apparent.

Hupé (1954, text-fig. 20) has repeated Størmer s diagrams, and also presented a curve (text-fig. 21, L) based on measurements made on Barrande's (1852) figures, showing the variation during ontogeny of the length of the "preantennal segment complex." Dr. Hupé informs me (personal communication) that he regarded the sagittal distance between the anterior margin of segment A_1 (the fifth, counting forward from the occipital ring) and the anterior margin of the cephalon as representing the length of the "preantennal segment complex." In *D. socialis* he evaluated this distance by assuming that segment A_1 had the same length as the immediately suceeding cephalic segments. Using this procedure on Text-fig. 2 the length of the "preantennal segment complex" is some 13% of the cephalic length, and applying it to the originals of Pl. 24, fig. 11, 12, the ratio is 18–20%. The slope of the curve L of Hupé's fig. 21 portrays a change in this ratio, with changing cephalic length, from about 8% to 21% and suggests that the ratio may be as low as 1% in the protaspis. This variation is excessive in the light of my observations.

The width (sag.) of the anterior border of *Dalmanitina* appears actually to show a relative (to the cephalic length) decrease during ontogeny, since in the holaspis (Pl. 24, fig. 12) there is a preglabellar furrow bounding the vertical slope of the frontal glabellar lobe, outside which the exoskeleton immediately curves under to form the doublure. The confluent anterior branches of the facial suture run along the outer edge of the preglabellar furrow.

It has already been pointed out (Whittington & Evitt, 1954, p. 27) that the metaprotaspides of various proparian genera—*Flexicalymene*, *Acanthoparypha*, *Protopliomerops*, *Pseudocybele*, and *Dalmanitina* have a general similarity in form, and the present investigation provides further evidence of this. It is because of this common early developmental form that the superfamily Phacopoidae is regarded as including calymenids, cheirurids, pliomerids, phacopids, etc. (Whittington, 1954; in this paper the name Cheiruroidae Öpik, 1937, was used in error, rather than the earlier name Phacopoidae, Richter, 1932).

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 110–112, PL. 25 (PART), JANUARY 1956

A NEW MISSISSIPPIAN TETRACORAL FROM DEATH VALLEY, CALIFORNIA

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ABSTRACT—A hapsiphyllid tetracoral, *Triplophyllites* (*Triplophyllites*) *californicus*, n. sp., was collected from the Perdido formation (Mississippian) in the northwestern portion of Death Valley National Monument, California. This coral is outstanding because of its large size and numerous septa. It is widely distributed in the Mississippian rocks of the Great Basin.

INTRODUCTION

DURING the summer of 1951, a collection of fossils was obtained from the area immediately south of Rest Spring, California, located in the northwestern portion of Death Valley National Monument, approximately in the center of the Quartz Spring area as mapped by J. F. McAllister (1952). The tetracoral described in this paper was collected from the Perdido formation (Mississippian) in Rest Spring gulch about 2300 feet south of Rest Spring (Tischler, 1955). It occurred in a layer of bedded, red and black crystalline limestone approximately 20 feet thick. This layer is stratigraphically below a fissile, purple shale, and is approximately 400 feet above the base of the Perdido formation. *Triplophyllites californicus*, n. sp., has been noted in widely scattered locations in the Great Basin and seems to be stratigraphically significant in the Mississippian rocks in that area (personal communication, R. L. Langenheim, Jr., January 17, 1955).

ACKNOWLEDGMENTS

The writer wishes to thank J. Wyatt Durham and R. L. Langenheim, Jr., who read the manuscript and offered many valuable suggestions. Thanks are also tendered to W. H. Easton and E. C. Stumm for their comments regarding the taxonomic position of this coral. Acknowledgements must also go to the members of the University of California Museum of Paleontology for their help in the preparation of this work, and to the U. S. National Park Service for permission to collect in Death Valley.

DESCRIPTION OF SPECIES

Family HAPSIPHYLLIDAE Grabau, 1928, emend. Easton, 1944

Genus TRIPLOPHYLLITES Easton, 1944

Subgenus TRIPLOPHYLLITES Easton, 1951

TRIPLOPHYLLITES (TRIPLOPHYLLITES) CALIFORNICUS, n. sp.

Pl. 25, fig. 7–10

External.—Simple, large, ceratoid; epitheca fairly thick, interseptal ridges, calyx steep walled, cardinal fossula on concave side; over-all length 80 mm., calyx about 30 mm. deep.

Transverse section.—Ephebic stage, diameter 45 mm.; 79 major septa in two series, long ones reaching axis and shorter septa slightly over one-half length of long septa; septa in counter quadrant averaging longer than those in cardinal quadrant; counter septum and septa immediately adjacent to it thickened; minor septa rudimentary in cardinal quadrant, never more than 2 mm. long; cardinal septum very short, becoming progressively shorter until nonexistent in calyx; cardinal fossula long, narrow, prominent just below calyx, becoming rapidly smaller toward apical portion of coral; alar pseudofossulae formed by shortening of alar septa.

Longitudinal section.—Tabulae complete, sloping down toward cardinal fossula, 6 in 10 mm.; dissepiments sparse, observed only on counter side of section.

Material.—Holotype: University of California Museum of Paleontology No. 14749; paratype: No. 14750.

Occurrence.—University of California Museum of Paleontology locality No. A-9456, Perdido formation.

Remarks.—This coral agrees with the characters of the genus *Triplophyllites*, s.s., having its long narrow cardinal fossula on the concave side of the corallite, few dissepiments, and prominent tabulae. The cardinal fossula on the concave side of the corallite and the presence of alar fossulae, according to Stumm (1949, p. 12), distinguishes *Triplophyllites* from *Heterophrentis* Billings, 1875, which has its cardinal fossula on the convex side of the corallite. When *Triplophyllites* was first proposed, dissepiments were thought to be "sparse, irregular, mostly in early portions of corallite . . . " (Easton, 1944, p. 35). Later it was discovered that dissepiments occur in early or late portions of the corallite (Easton, 1951, p. 394) and that subdivision of the genus *Triplophyllites* could be based upon the position of the cardinal fossula on the concave or convex side of the corallite, and upon the circular or cuneate transverse section of the corallite. The subgenus *Homalophyllites* erected in 1944, by Easton, for the genus *Hapisphyllum* Simpson, 1900, was subsequently assigned to *Triplophyllites* (Easton, 1951, p. 398). It embraced those species with the cardinal fossula on the convex side and thus complemented the subgenus *Triplophyllites* whose species have the cardinal fossula on the concave side of the corallite.

Although this broadens the genus to the extent that the members within the subgenus *Homalophyllites* seem to be congeneric with the members of *Heterophrentis*, it might be asserted that the two groups maintain their separate identities by the presence of alar fossulae in *Homalophyllites* and their absence in *Heterophrentis*. The presence or absence of alar fossulae is considered by Easton (1944, p. 38) as well as by Stumm (1949, p. 12) to be one of the more important distinguishing characters between *Triplophyllum* (=*Heterophrentis*) and *Triplophyllites*. In any event the taxonomic position of *Homalophyllites* cannot affect the status of *Triplophyllites* s.s. *T. californicus* and the other species of *Triplophyllites* s.s. are clearly distinguishable from the members of *Heterophrentis* and *Homalophyllites* by the position of the cardinal fossula.

Triplophyllum Simpson, 1900, a junior synonym of *Heterophrentis*, cannot be considered as the genus of this species. In 1944, Easton (p. 38) put all but two species of *Triplophyllum* [the genotype, *Zaphrentis terebrata* Hall and *T. edwardsi* (Nicholson), both Onondogan] into *Triplophyllites*. Then in 1949, Stumm (p. 12) noted that *Triplophyllum* was congeneric with *Heterophrentis*.

In general appearance *T.* (*T.*) *californicus* resembles *T. illinoisensis* (Worthen) (1890, p. 77, pl. 20, fig. 4). They both attain large size, but *T. californicus* has almost twice as many major septa as *T. illinoisensis*. The dimensions of *T. illinoisensis* are: diameter 52 mm., length 73 mm., and depth of calyx 25 mm. It is reported from the Osagean of Illinois and Missouri. Grove (1935, p. 342), in reviewing *Triplophyllum* said: "Actually it seems impossible to find a Mississippian Zaphrentid with as many as 60 septa." In comparison with *T. californicus*, some species of *Triplophyllites* with their diameter and number of septa are listed below.

	Diameter (mm.)	Number of septa
Triplophyllites californicus, n. sp.	45	79
T. illinoisensis (Worthen)	52	40
T. palmatus Easton	15.8	34
T. centralis (Edwards & Haime)	15	40
T. cliffordanus (Edwards & Haime)	11.2	30
T. exiguus (Miller)	15	30
T. ida (Winchell)	27	31
T. ellipticus (White)	18	38
T. clinatus (Green)	18	34

The U. S. Geological Survey (personal communication, W. H. Easton, April 1, 1953) possesses a specimen of this coral from the lowest Perdido formation whose dimensions are: diameter 76 mm., length 152 mm., and depth of calyx 51 mm.

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MANUSCRIPT RECEIVED APRIL 20, 1955

EXPLANTATION OF PLATE 25 (PART) (*See Page 114*)

FIG. 7–*10*—*Triplophyllites* (*Triplophyllites*) *californicus* Tischler, n. sp., ×1; holotype No. 14749. 7, calicular section; note absence of cardinal septum, 14749a. *8*, transverse section, ephebic stage, 7 mm. below calicular section; note narrow cardinal fossula, cardinal septum absent, 14749b. *9*, transverse section, ephebic stage, 12 mm. below calicular section; note shortened cardinal fossula, cardinal septum present but very short; note also longer thicker septa in counter quadrant, and presence of alar pseduofossulae, 14749c. *10*, longitudinal section, through cardinal fossula, taken below section of 14749c; note slope of tabulae toward cardinal fossula, 14749d. (p. 110)

JOURNAL OF PALEONTOLOGY, VOL. 30. NO. 1, P. 113–114, PL. 25 (PART), 1 TEXT-FIG., JANUARY 1956

THE TRANSFORMATION OF OPAQUE CALCIUM CARBONATE TO TRANSLUCENT CALCIUM FLUORIDE IN FOSSIL OSTRACODA[1]

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ABSTRACT—Calcium fluoride replacement of fossil ostracode shells by treatment with hydrofluoric acid yields translucent specimens which may reveal details of shell morphology not otherwise visible. A simple procedure is outlined and results illustrated.

I. C. Cookson and O. P. Singleton recently (1954) obtained startling results from the preparation of a sample of marine clay of Miocene age for fossil pollen using Erdtman's method. The Erdtman method (1943, p. 36) uses hydrofluoric acid as a preliminary step to remove silicon dioxide. The sample treated by Cookson and Singleton contained Foraminifera and Bryozoa in which the original calcium carbonate was replaced by calcium fluoride. When wetted, these fossils became translucent and revealed internal structures. Experiments with calcareous fossils resulted in recommendation of this method for conversion to translucency of smaller Foraminifera, Bryozoa, and certain groups of Brachiopoda (Cookson & Singleton, 1954, p. 2). Apparently they did not experiment with Ostracoda.

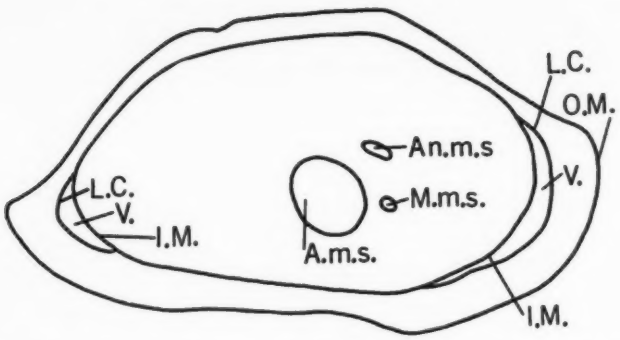
Their method can be used to advantage in the study of Ostracoda, because calcareous opaque specimens that are treated with hydrofluoric acid become either translucent or transparent when wet. This may disclose hitherto unsuspected criteria for taxonomic relationship.

In living and post-Paleozoic Ostracoda the shell varies from opaque to translucent depending on the genus and the stage of growth represented by the individual specimen; in some genera, young individuals are somewhat translucent. Features such as the position and pattern of the muscle scars, and shell structures such as pore canals and duplicature are studied by wetting the specimen and examining it with either transmitted or reflected light (Scott, 1944, p. 162). Paleozoic Ostracoda are generally opaque, probably because of preservation. The limited data available on shell structures and muscle scar features are obtained from a few fortuitously preserved or partly abraded specimens, and from internal impressions. One way to overcome this difficulty is by use of radiographs. The muscle scar pattern in a carapace of *Pseudophanasymmetria* was obtained in this manner by Sohn and Berdan (1952, fig. 3).

I have used the following process on ostracodes that range in geologic age from the Ordovician to the Recent, without any discernible damage to the specimens.

A selected specimen is placed in a platinum dish of 1-inch diameter and $\frac{3}{8}$-inch depth with sufficient tap water added to cover the specimen. A few drops of 20 percent by volume (10 percent by weight) hydrofluoric acid are added, and trains of small bubbles begin to rise from the specimen. After 2 to 24 hours, depending on the size of the specimen, the bubbling stops, and the specimen is either transparent or translucent. Because of the corrosive effects of the acid, the following washing technique is used: The small dish is placed in a larger platinum evaporating dish $2\frac{1}{4}$ inches in diameter and 1-inch deep, and the acid is flushed with tap water using a dropping pipette. Water is added until the level of the dilute acid, which has run over into the larger dish, is above the rim of the smaller dish. The small dish is then removed with platinum-tipped tongs and placed in a second platinum evaporating dish. The flushing process may either float or force the specimen out of the small dish, thus making it necessary to examine the dish with a microscope. The meniscus which is formed in receptacles of less than one inch diameter makes it difficult to see the specimen inside. If the specimen remains in the small dish, the dilute acid in the larger receptacle is discarded, and the process repeated. Should the specimen wash out into the larger dish, this dish is placed in a still larger receptacle and flushed with tap water. After five washings, the water is removed with a pipette, and the specimen can then be handled with

[1] Publication authorized by the Director, U. S. Geological Survey.



TEXT-FIG. *1*—*Bairdia whitesidei*. Tracing of Pl. 25, fig. 3 in order to identify the following: A.m.s.—Adductor muscle scars; An.m.s.—Antennal muscle scar; M.m.s.—Mandibular muscle scar; I.M.—Inner margin; L.C.—Line of concrescence; O.M.—Outer margin; V—Vestibule.

a fine camel hair brush and mounted in glycerin for study.

Best results are obtained by using clean dissociated valves. Complete carapaces treated in this manner have, in some cases, shown a steinkern upon which the position of the adductor muscle scar can be discerned. The treated specimen of *Bairdia whitesidei* Bradfield, 1935, from the Deese formation of Pennsylvanian age (Pl. 25, fig. 3) was photographed from the outside to show the degree of transparency sometimes attained by this method. Scars interpreted as the antennal and mandibular muscle scars, line of concrescence and vestibule are visible (Text-fig. 1). These structures are not discernible on the calcareous specimen (Pl. 25, fig. 4, 5) or the dry calcium fluoride specimen (Pl. 25, fig. 1, 2). Such structures, if disclosed by this method, would probably clarify many problems of orientation and taxonomic relationship among fossil ostracode genera.

I am indebted to M. K. Carron, of the U. S. Geological Survey, for equipment and laboratory facilities during the initial stages of this work. Photographs with transmitted light were made by J. A. Denson; with reflected light by H. N. Shupe, U. S. Geological Survey.

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EXPLANATION OF PLATE 25

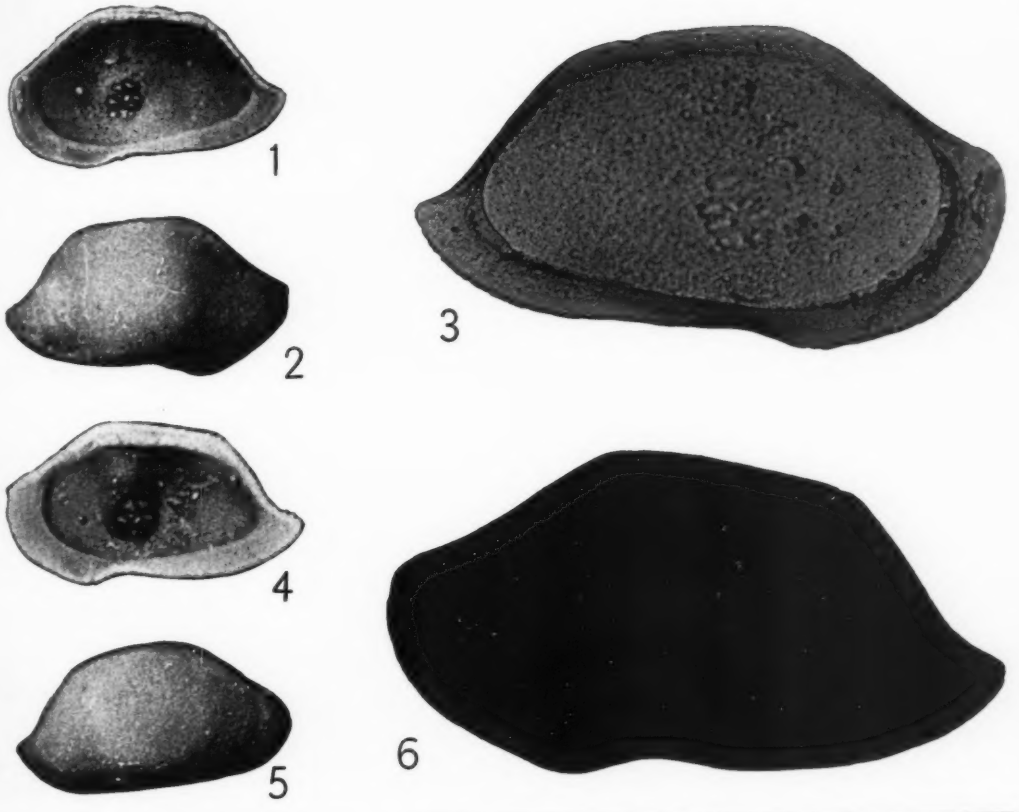
The transformation of opaque calcium carbonate to translucent calcium fluoride in fossil Ostracoda; by I. G. Sohn

FIG. *1–6*—*Bairdia whitesidei*, *1–3*, Right valve converted to calcium fluoride, USNM 119206. *1*, Inside view, ×25. *2*, Outside view, ×25. *3*, Outside view in glycerin with transmitted light, ×50. *4–6*, Right valve, untreated, calcium carbonate, USNM 119207. *4*, *5*, Inside and outside views, ×25. *6*, Inside view in glycerin with transmitted light, ×50. Devils Kitchen member of Deese formation (Tomlinson, 1930), about 150 feet SE of NW corner sec. 4, T. 6 S., R. 2 E., Love Co., Oklahoma.

A new Mississippian tetracoral from Death Valley, California; by Herbert Tishcler

FIG. *7–10*—*Triplophyllites* (*Triplophyllites*) *californicus*, n. sp., ×1; holotype UC 14749. *7*, Calicular section; note absence of cardinal septum, 14749a. *8*, Transverse section, ephebic stage, 7 mm. below calicular section; note narrow cardinal fossula, cardinal septum absent, 14749b. *9*, Transverse section, ephebic stage, 12 mm. below calicular section; note shortened cardinal fossula, cardinal septum present but very short; note also longer thicker septa in counter quadrant, and presence of alar pseudofossulae, 14749c. *10*, Longitudinal section, through cardinal fossula, taken below section of 14749c; note slope of tabulae toward cardinal fossula, 14749d.

(p. 110)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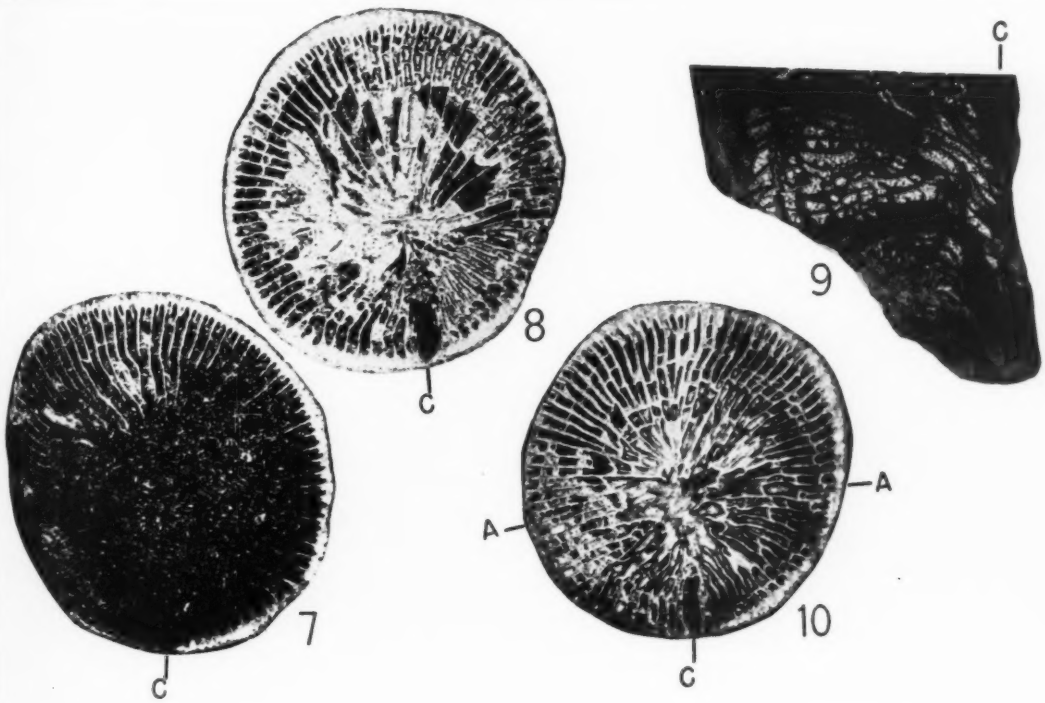
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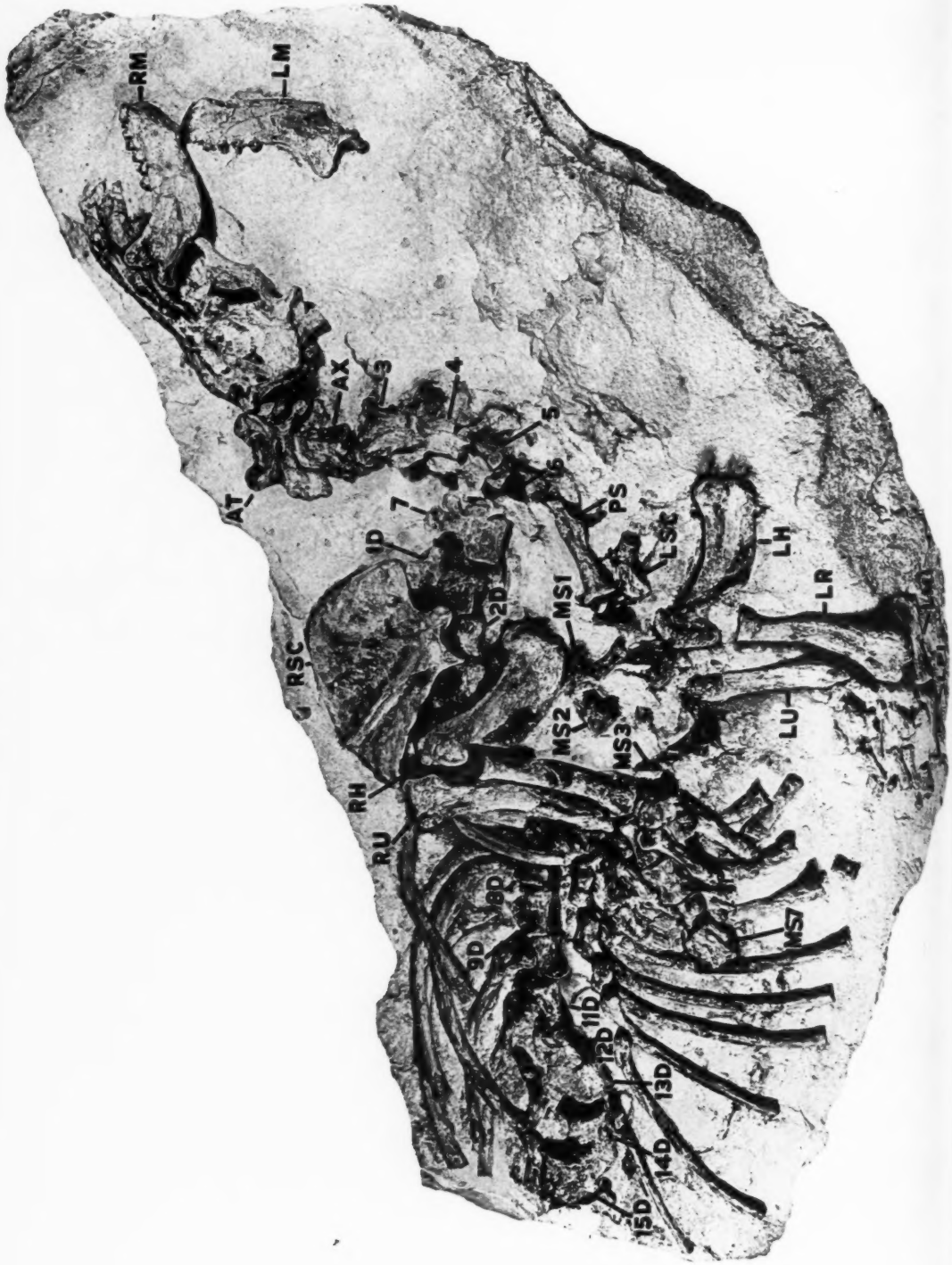
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A NEW PINNIPED FROM THE MIOCENE OF SOUTHERN CALIFORNIA: WITH REMARKS ON THE OTARIIDAE

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ABSTRACT—An unusually complete fossil skull with partial skeleton of an eared seal, family Otariidae, is described as a new genus and species, *Atopotarus courseni*. It was found in the middle Altamira member of the Monterey formation of the Palos Verdes Hills of southern California and is dated as late middle or early upper Miocene age. The new genus is distinctive, yet is basically similar to other known Miocene pinnipeds, especially *Allodesmus* and *Desmatophoca*. The genera, *Otaria* from the southern hemisphere, and *Zalophus* of North America, are remotely allied Recent pinnipeds. The new fossil was a medium-sized animal, about the size of male *Zalophus californicus*, the California sea lion. It had a large skull and canines, strong neck and short fore limbs.

In the family Otariidae, the genera *Allodesmus*, *Atopotarus*, *Dusignathus*, *Pithanotaria*, *Pontolis*, *Callorhinus*, *Arctocephalus*, *Eumetopias*, *Zalophus* and *Otaria* are based on equally significant characters and are best considered as distinctive genera. *Desmatophoca*, *Pliopedia* and *Arctophoca* are probably valid, but *Neotherium* and *Neophoca* are less positively defined on the basis of present knowledge.

Many features of the humerus, scapula, radius, ulna and mandible in Miocene pinnipeds show common traits and suggest possibly less (or at least a different) aquatic adaptation of the fore limb in these fossil forms than in Recent otariids.

The apparent sudden appearance of many genera of otariids well adapted to aquatic existence may demonstrate the occurrence of quantum evolution in this group of mammals.

INTRODUCTION

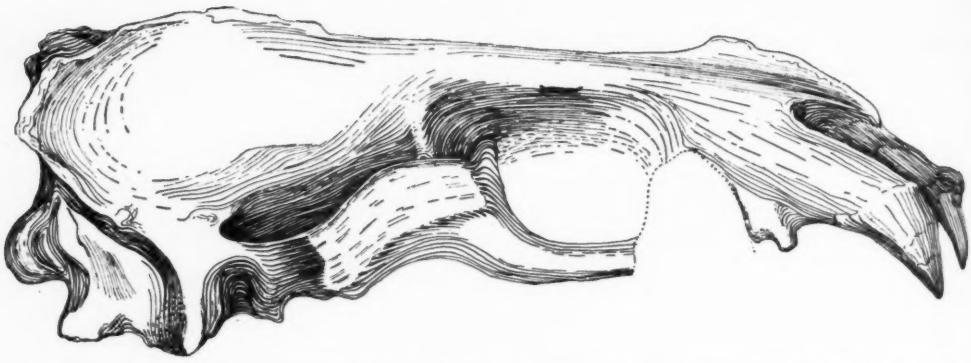
ONE of the most complete known records of a Tertiary pinniped has been discovered in the scenic residential area of Palos Verdes Hills, south of the city of Los Angeles proper. The specimen represents all but the hind quarters of the skeleton referable to an extinct genus of the family Otariidae.

The Los Angeles County Museum (hereinafter abbreviated LACM) is especially indebted to Mr. and Mrs. Walter H. Coursen, Jr., of Rolling Hills, California. The Coursens, realizing the significance of the fossil animal allowed personnel from the museum to extract the specimen from their garden walk. The fossil was originally dug out of the backyard of the Coursens' residence, by former owners of the property. The residence rests on rocks of Miocene age in the middle of the Altamira shale member of the Monterey shale, as mapped by Woodring, Bramlette & Kew (1946). The rock bearing the specimen is described by the late Dr. R. J. Barber, Curator of Mineralogy and Petrology of the Los Angeles County Museum, as a hard, siliceous limestone with parallel layers of opaline chert which occasionally replaced portions of the actual skeleton.

The significance of this material as an unusually good record of a pinniped, is paralleled by the artistry and technique of the preparation of the specimen by Mr. William P. Otto. The fossil arrived in Otto's laboratory in two large, highly indurated blocks; one half of the specimen lay in each block. As now prepared, the

EXPLANATION OF PLATE 26

Atopotarus courseni, n. gen., n. sp. Holotype, LACM 1376. Lateral view of skull, mandibles and partial skeleton in place in original matrix. RM = right mandible, LM = left mandible, AT = atlas, AX = axis, 3–7 = cervicals, 1D–15D = dorsals, RSC = right scapula, LSC = left scapula, RH = right humerus, LH = left humerus, RU = right ulna, LU = left ulna, LR = left radius, LMI = left metacarpal I, LPI = left proximal phalanx I, PS = presternum, MS3 = mesosternum, 3 MS7 = mesosternum 7. Photo by Mr. J. A. Meade.



TEXT-FIG. *1*—*Atopotarus courseni*, n. gen., n. sp. Holotype, right lateral view of partial skull, LACM 1376, ×½

bones have been brought together on one block. In a few instances it was necessary to make casts of the bones on one block, put them in place on the permanent block and then extract the paper-thin layer of bone lining the molds from which the casts were made. These bone "skins" were transferred to the outer surface of the casts. Other parts of bones were left in place but required the elimination of the hard, and, in some instances, opalized matrix surrounding them. The preparation of the material was completed prior to the arrival of the author at the Los Angeles Museum.

I am greateful for criticisms and advice offered by Dr. Hildegarde Howard, Dr. J. A. Shotwell, Dr. G. A. Bartholomew, Jr., and Dr. Fred S. Truxal. I am particularly indebted to Dr. Shotwell for supplying measurements of the type skull of *Desmatophoca* and placing at my disposal several important undescribed specimens from the Museum of Natural History, University of Oregon. Mrs. Gretchen (Lyon) Humason of the University of California at Los Angeles supplied much helpful information and made it possible for the loan of critical material. Drs. L. G. Hertlein and R. T. Orr of the California Academy of Sciences, San Francisco, graciously assisted me in obtaining Recent and fossil material from their institutions, Dr. David H. Johnson sent material for comparison from the United States National Museum, as did Miss Barbara Lawrence from the Museum of Comparative Zoology, Harvard College. Dr. R. A. Stirton of the Museum of Paleontology, University of California, Berkeley, permitted the study of type and other fossil material from that institution. Thomas M. Heric, a student helper, aided in recording data on measurements of Recent material; D. E. Phillip, Museum Artist, assisted in inking of the drawings and drafting the ratio diagrams.

DESCRIPTION OF MATERIAL

Order PINNIPEDIA

Family OTARIIDAE

ATOPOTARUS COURSENI,* n. gen., n. sp.

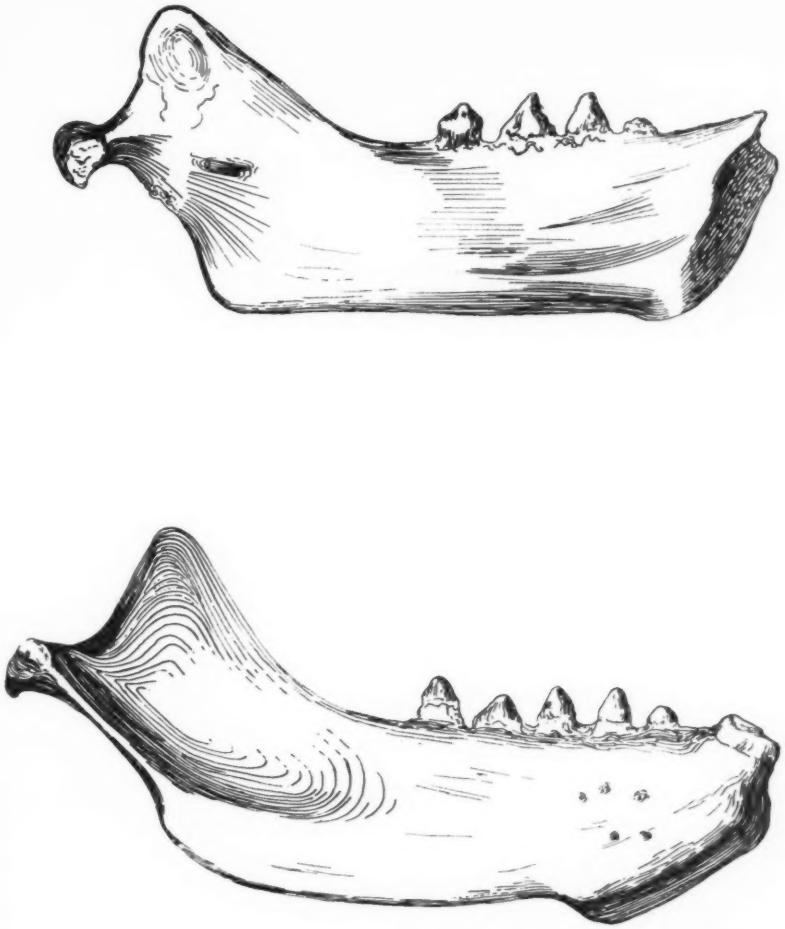
Pl. 26; Text-fig. 1–4

Holotype.—Incomplete skeleton (lacking hind quarters) including the following elements: right half of skull (exposed dorsolaterally) with incisor 3, canine, imperfectly preserved P^2, P^3 and indeterminate molars; nearly complete right and left mandibles; cervical vertebrae; dorsal vertebrae except four, five and six; ribs 9–14 (left and right); sternal elements exposed in ventral view; right scapula and articular surface of left scapula; right and left front limb elements, but only indistinct outlines of most of the carpals and metacarpals. LACM 1376.

Type locality.—LACM loc. 1098; W. H. Coursen residence, 3 Meadowlark Lane, Rolling Hills, Los Angeles County, California; directly west of hill 443 and north 7° west of hill 918 (see Woodring, et al., 1946, geol. map).

Formation.—Middle Altamira shale member of the Monterey shale.

* *Atopotarus*: atopus, m. (ἄτοπος), strange; otarus, m. (ὦτα̃ρος), large-eared; *courseni*: in honor of Mr. Walter Coursen, Jr.

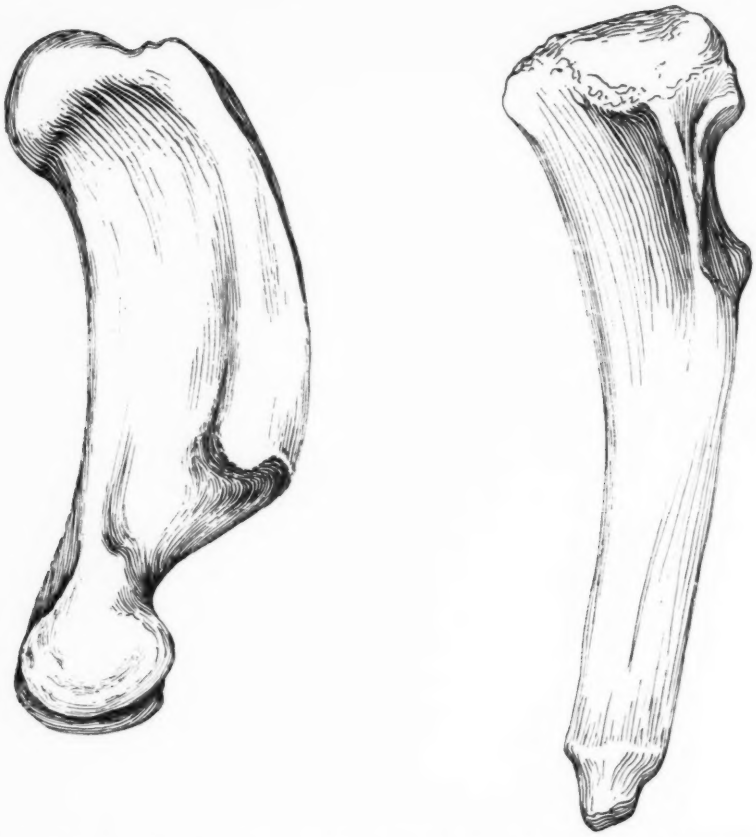


TEXT-FIG. 2—*Atopotarus, courseni*, n. gen., n. sp. Holotype, left and right mandible, external and internal view respectively, LACM 1376, ×½

Age.—Late Hemingfordian or early Barstovian (late middle or early upper Miocene).

Diagnosis of genus.—Squamosal part of zygomatic arch much deeper dorsoventrally than jugal portion of arch; large, broadly based upper canine; spacing between cheek teeth in mandible averages 5.8 mm.; cheek teeth tend to increase in size from anterior to posterior; symphysis elongate-narrow, slightly rugose; posterior margin of ascending ramus between angle and condyloid process an extremely narrow ridge; deltoid of humerus ascends sharply in narrow ridge connecting with area of coronoid fossa; scapula with enlarged coronoid process and prescapular broadly convex with relatively plain surface; atlas large with widely expanded transverse processes; axis with relatively long centrum compared with other cervicals; ulna with wide, massive radial process and moderately developed ulnar process, and small, shallow radial notch; presternum with point of attachment of first rib near mid point; ribs strong and with generally rounded surfaces; front appendages short.

Diagnosis of species.—Same as that of the genus until other species become known.

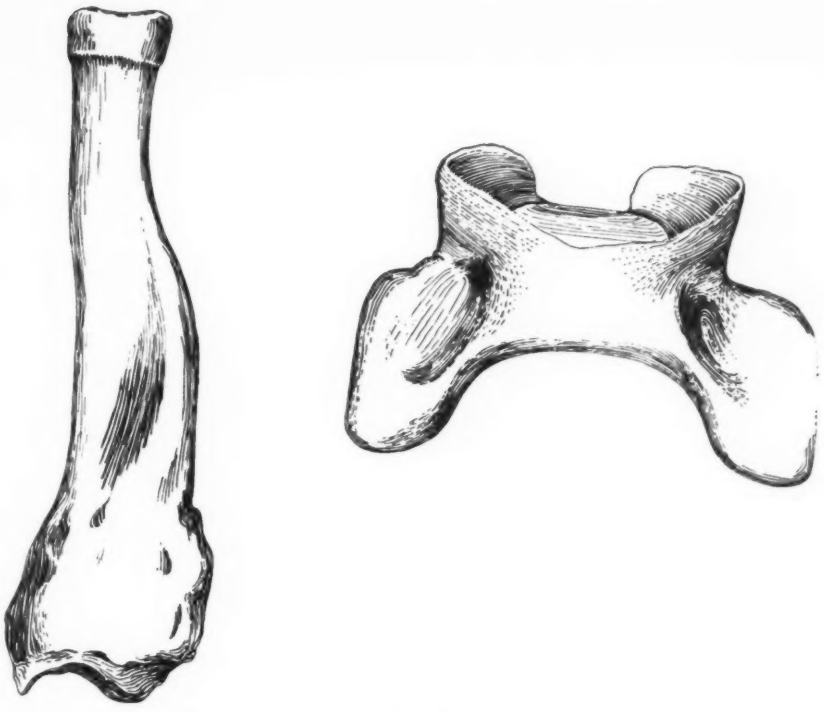


TEXT-FIG. 3—*Atopotarus courseni*, n. gen., n. sp. Holotype, right humerus (left drawing) and right ulna, lateral views, LACM 1376, ×½

Description.—Age and sex: slight wear on M_1 of right mandible, lack of development of sagittal crest and moderate size of animal (slightly smaller than female *Eumetopias*) suggest it may have been a young adult. In *Zalophus*, for example, male specimens show variations from practically no crest present in young males to a very prominent crest in older males. No evidence to indicate definite immaturity; ends of bones seem to be firmly fused, with no indication of separate epiphysis. Certain features of skull and mandibles, such as stout zygomatic arch, large canines, rugose lambdoidal crest and well developed atlas in post cranial skeleton suggest this animal may have been a male. Refer to Table 1 and Text-fig. 5 for detailed measurements and for comparisons with related genera.

Body proportions and size: Estimated total length, plus or minus 175 centimeters, based on comparison with *Eumetopias* (♀) skeletal length and assuming *Atopotarus* has similar proportions in its posterior vertebrae (lumbar to caudals). A moderate-sized sea lion with relatively large head and anterior neck vertebrae; strongly built scapula, sternum and ribs. Fore limbs short but stoutly constructed. See Text-fig. 5 for comparisons with longer limbed Recent genera, *Eumetopias*, and *Otaria*.

Skull.—View of skull in rock is from dorso-lateral at about a 45° angle relative to sagittal plane; due to slight distortion in preservation. Nasals elevated in apparently abnormal position, left cranial surface slightly uplifted, and dorsal border of zygomatic arch has been twisted slightly



TEXT-FIG. 4—*Atobotarus courseni*, n. gen., n. sp. Holotype, internal view of left radius, and ventral view of atlas, LACM 1376, ×½.

mesially. Distinction of bone from opalized matrix is not possible in regions of maxillae and lachrymal. Right ascending ramus lies over anterior part of zygomatic arch and anterior orbital region, thus obliterating this area; and internal aspect of paraoccipital mastoid area may be lost in part. Dorsal profile is in general parallel to horizontal plane of tooth row or palate (very slight ventral inclination from posterior to anterior). Skull somewhat elongate, with deep snout (about ¼ length of skull).

Postorbital process apparently represented by a rudimentary angular ridge. Though skull is distorted in area of postorbital constriction, the region is in general long and narrow to anterior base of brain. Orbital outline spherical and probably large (estimated anteroposterior diameter 60 mm.). Sagittal crest only a gentle median ridge with slight prominence at extreme posterior. Lambdoidal (supraoccipital) crest strongly developed, particularly in midportion which extends well beyond exoccipital plane to a point nearly in line with posterior edge of occipital condyle with dorsal aspect of crest reduced and ventral portion curving sharply forward to join base of paraoccipital mastoid process. Only a portion of occipital condyle is revealed; and shows anterior edge to be abrupt with slight curvature (directly posteriorly) on dorsolateral surface. Brain case moderately convex surface with remnants of a process or ridge 16 mm. posterior to orbital process of jugal and suggestions of irregular small ridges over surface of parietals. Prominent horizontal ridge on temporal surface of brain case, 12 to 13 mm. above base of zygomatic arch. Mastoid and paraoccipital are fused and have long anteroposterior dimension, with mastoid process projecting below level of posterior glenoid ridge and paraoccipital shorter than mastoid process but extending posterior and slightly lateral (mastoid process is 12.4 mm. posterior to edge of glenoid).

Zygomatic arch: Most distinctive char-

TABLE 1.—MEASUREMENTS OF *Atopotarus courseni*, LACM 1376 (in millimeters)

Skull:		
Tip of snout to posterior edge occipital condyle		277.0
Orbital process of jugal to tip of snout		157.0
Orbital process of jugal to anterior edge occipital condyle		132.0
Greatest anteroposterior diameter paraoccipital and mastoid		50.4
Posterior edge paraoccipital to anterior edge occipital condyle		13.0
Anteroposterior diameter zygomatic arch		78.5
Transverse diameter interorbital constriction (above center of orbit)		26.5
Posterior edge glenoid to anterior edge mastoid		12.3
Dorsoventral diameter zygomatic arch at midpoint of squamosal and posterior jugal process		32.2
Dorsoventral diameter of squamosal at midpoint		23.0
Dorsoventral diameter of posterior process of jugal at midpoint		9.2
Least dorsalventral diameter jugal (anterior)		12.7
Greatest transverse diameter zygomatic arch (thickness)		12.0
Anteroposterior diameter glenoid (ridge to ridge)		18.4
Anteroposterior diameter canine at base		24.6
Length (base to tip, unworn) canine		32.9
Mandible:	*Left*	*Right*
Greatest length	—	204.0
Greatest length molariform series	—	65.2
Depth coronoid process to angle of ramus	79.6	77.7
Depth at P_3	40.3	43.2
Depth at M_1	41.3	45.0
Thickness at P_3	—	13.2
Thickness at M_1	—	11.3
Length posterior edge symphysis to angle of ramus	121.0	(117.5)*
Least distance across ascending ramus	48.0	46.5
Length symphysial area	—	66.4
Greatest anteroposterior diameter symphysial area	18.0	—
Transverse diameter condyloid process	33.0	35.7
Posterior edge condyloid process to anterior extreme masseteric fossa	—	96.0
Acute angle formed by axis of symphysial area with horizontal axis of ramus	25.0°	26.0°
Acute angle formed by anterior border ascending ramus with horizontal axis of ramus	—	50.0°
Lower dentition:		
Anteroposterior diameter canine (ab base)	—	18.3
Anteroposterior diameter P_1 (at base)	—	(8.2)
Anteroposterior diameter P_2 (at base)	—	8.6
Anteroposterior diameter P_3 (at base)	11.3	9.6
Anteroposterior diameter P_4 (at base)	12.6	10.4
Anteroposterior diameter M_1 (at base)	12.5	10.2
Anteroposterior diameter diastem, C–P_1	8.5	(8.8)
Anteroposterior diameter diastem, P_1–P_2	5.0	4.5
Anteroposterior diameter diastem, P_2–P_3	6.7	6.3
Anteroposterior diameter diastem, P_3–P_4	4.5	(3.5)
Anteroposterior diameter diastem, P_4–M_1	4.5	(6.0)
Scapula:		
Transverse diameter neck	—	27.3
Anteroposterior diameter neck	—	61.5
Anterior edge coronoid process to posterior edge glenoid	—	62.3
Coracovetebral angle to inferior angle	—	(232.0)
Anteroposterior diameter glenoid cavity	47.5	51.9
Transverse diameter glenoid cavity	—	40.5
Height of spine above external edge glenoid	—	17.6
Base of acromion to edge of glenoid	—	18.4
Humerus:		
Greatest length (head to inner trochlea)	(187.4)	187.3
Distance head extends beyond greater tuberosity	—	13.3
Length of deltoid crest	115.4	(124.0)
Greatest distal transverse diameter	(70.0)	(67.0)
Greatest anteroposterior diameter head	—	45.5
Greatest anteroposterior diameter distal end	—	37.5
Proximal transverse diameter deltoid crest	—	25.6
Greatest anteroposterior diameter at deltoid crest	—	60.5
Radius:		
Greatest length	184.0	(165.0)
Greatest anteroposterior diameter, proximal	28.3	26.9
Greatest anteroposterior diameter, distal (at tip of extensor metacarpi pollicis)	48.1	—
Least anteroposterior diameter, 60 mm. from proximal end	23.6	(27.4)
Greatest anteroposterior diameter at pronator teres	(28.0)	29.0
Greatest transverse diameter proximal	—	34.5
Greatest transverse diameter distal	(31.0)	—
Distance proximal end to pronator teres	(72.2)	66.0
Anteroposterior diameter surface carpals	31.8	—
Ulna:		
Greatest length	—	218.5
Greatest length sigmoid, external	—	29.3
Greatest anteroposterior diameter at olecranon process	—	62.0
Greatest anteroposterior diameter above styloid process	27.5	28.4
Greatest anteroposterior diameter at cornoid process	—	44.6

TABLE 1.—(*Continued*)

Sternum:

Presternum	
Greatest length	112.0
Distance 1st rib attachment to distal end	58.0
Least transverse diameter	12.0

Vertebrae:

	Atlas	Axis	3rd	4th	5th	6th	7th
Cervicals:							
Anteroposterior diameter at centrum	23.1	55.7	48.0	46.5	52.6	(51.0)	50.3
Transverse diameter centrum	—	—	32.0	—	(38.0)	41.0	—
Length transverse process	—	31.5	39.7	—	—	—	46.0

Dorsals: Anteroposterior diameter at centrum

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th
44.0	39.7	40.6	—	—	—	(40.0)	(42.5)	47.0	45.5	42.6	43.0	44.4	44.3	45.0

Ribs: right side	6th?	7th?	8th?	9th	10th	11th	12th	13th	14th
Length from tip to tip	—	—	—	282.0	268.0	245.0	217.0	238.0	—
Capitulum to tuberculum	—	—	—	37.0	37.3	—	—	—	—
Anteroposterior diameter distal end of rib	21.6	20.2	22.4	20.3	17.3	17.0	15.3	14.0	—

Mesosternum:	1st	2nd	3rd	4th	5th	6th	7th
Anteroposterior diameter	39.7	—	—	48.8	47.7	—	48.0

Right Manus:

	Metacarpal					Proximal phalanx			Median phalanx	Distal phalanx
	I	II?	III?	IV?	V?	I	IV	V	V	V
Greatest Length	96.4	—	(59.0)	—	(56.0)	79.3	54.0	38.0	8.0	21.3
Proximal trans. diam.	—	—	—	—	—	21.2	—	16.0	12.8	15.0

Left Manus:

	Metacarpal				Proximal phalanx			
	I	II	III	IV	I	II	III	IV
Greatest length	100	—	—	—	82.5	65.5	44.0	(36.0)
Distal transverse diameter	33.0	(20.3)	—	—	19.9	—	—	—

• Measurements in parentheses are approximations.

acter of genus is extreme dorsoventral depth of anterior squamosal portion of arch as compared to extremely small jugal. Squamosal laterally compressed with squared anterior end (may have been deflected slightly inward at base near glenoid—but otherwise bone in natural state). Zygomatic process of jugal narrow, rounded, much smaller than adjacent squamosal. Orbital process of jugal narrow with strongly convex dorsal margin and terminating in narrow blunt point beyond tip of squamosal. Basal anterior portion of jugal shallow dorsoventrally with slightly convex external surface and flattened dorsal surface. Glenoid fossa with posterior border extending slightly more ventral than anterior border. Articular surface of glenoid moderately concave and narrow anteroposteriorly.

The zygomatic arch is disproportionately formed; but to function as a support for the masticatory muscles it would seem the bridge or zygomatic arch would require equal size of the squamosal and jugal—otherwise the structure would be weakened. Until other specimens are available for comparison, this feature (the reduced jugal) must be considered as possibly biologically abnormal or an unusual specialization and thus of limited taxonomic and phylogenic significance—even though clearly distinctive as we know the record of fossil and Recent pinnipeds.

Dentition: Incisor 3 large but about half the size of the large, broadly based canine; P^3 as preserved is abnormally small, and was broken in preparation. Seemingly an unerupted tooth is in position about 5 mm. anterior to zygomatic arch, possibly a rudimentary tooth (for example LACM 419, male *Zalophus* bears an undeveloped P^1). Maxillary dental formulae not determinable.

Mandible.—Most of mandibular parts are well preserved except for slight obliteration in mandibular notch area and broken angular process. Right M_1 shows natural wear; other teeth may have had their anterior and posterior surfaces modified in preservation or preparation.

Ramus nearly straight without marked inflection as in later otariids. It is deep dorsoventrally but not massive, transversely

narrow in the posterior half, ascending sharply at a 55° angle relative to horizontal plane of tooth row (gradual ascent begins immediately posterior to M_1), and shows no dorsoventral constriction posteriorly. Coronoid process small anteroposteriorly with small but deep depression on dorsointernal surface. Mandibular notch shallow with broadly concave border. Condyloid process small and rounded posteriorly. Angular process near condyloid process, possibly moderately developed. Angle (posteroventral border) of right mandible rounded, and left angle angular (may be distorted due to preservation). Ventral margin of ramus straight to slightly convex in outline. Posterior margin, between angle and condyloid, a narrow ridge throughout its length. Symphysial surface elongate-narrow outline, slightly rugose, with posterior termination below P_2. Chin rounded but short dorsoventrally. Genial tuberosity rounded and prominent. External surface of ramus flat posteriorly to slightly convex anteriorly. Internal surface flat to slightly concave anteriorly. Mandibular foramen prominent, elongate and situated immediately below the center of the coronoid process and opposite dorsal tip of angular process. Masseteric fossa shallow but wide dorsoventrally with anterior termination about 18 mm. posterior to M_1. Six mental foramina are visible slightly dorsal and grouped below P_2 and P_3.

Dentition: Canine well developed with diastem between canine and P_1 (8.8 mm., right side). Cheek teeth evenly spaced, averaging 5.8 mm. separation. M_1 larger than other cheek teeth and teeth increase slightly in size from anterior to posterior. Two roots on right P_2, left P_3, P_4 and no less than two on right M_1, with roots widely diverging from base of tooth. Cheek teeth blunt tipped, cusp at center with smooth, bulbous basal portion, anterior and posterior surfaces are flattened (possibly due to preparation, except in left M_1 which shows slight anterior wear only and moderate anterior wear on right M_1).

Scapula.—Right scapula exposed except for part of vertebral border; left scapula in position below presternum with one half of glenoid and coronoid process visible. Right coronoid reconstructed from external mold in matrix. Scapula fan shaped and broad anteroposteriorly. Coracovertebral margin extremely angular so that border connecting with coronoid process is parallel with anteroposterior axis of glenoid facet. Neck markedly short from base of acromion to edge of glenoid and wide in anteroposterior diameter but narrow transversly. Coronoid process well developed and bulobus. Spine a thin, low ridge. Acromion projects much beyond level of spine as an elongate nearly flattened process with posterior border projecting about 12.0 mm. beyond spine. Glenoid cavity oval shape and moderately concave. Axillary border thin, with straight edge, ascending directly from base of neck. Prescapular fossa with irregular, convex surface and without a median ridge. Postscapular fossa deep, concave and much smaller than prescapular fossa. Superior border broadly curved with thick edge.

Humerus.—Right humerus exposed in lateral view near right scapula and well preserved. Head and shaft taken from mold lined by "bone skin." Left humerus exposed in posterior, internal view and morphology of distal region obscure; greater and lesser tuberosity are from an external mold. Humerus relatively slim, straight element with gently curving posterior border of shaft, and narrow, strongly convex posterior surface. Greater tuberosity; in position distal relative to head of humerus, about 13.0 mm., moderately thickened transversely. Deltoid crest with slight distal internal and external overhand; ascends sharply from coronoid fossa area. Only slight internal-external twist of deltoid relative to long axis of shaft, with proximal portion directed externally and with deep anteroposterior diameter. Supracondylar process absent, and narrowly convex external margin of shaft in this region. Head small, its anteroposterior axis forms an acute angle of about 30° to 35° relative to long axis of shaft. Intertrochlear groove narrow and deep. Lesser tubercle thickened proximally (29.5 mm. greatest diam.). Medial condyle moderately developed (relatively narrow distal, transverse diameter compared to recent otariids). Posterior trochlea narrow and with narrowly convex surface (lateral edge absent). Olecranon fossa narrow and shallow. Coronoid fossa

shallow and bordered by narrow lateral ridge connecting with deltoid. External condyle more anterior than medial condyle.

Radius.—Neither radii completely preserved; left radius with shaft restored above level of pronator teres. Distal half of right radius highly mineralized and somewhat compressed with apparent obliteration of radial process area. Relatively sturdy bone with only slight lateral compression. Curvature of shaft moderate as seen especially in right radius (left radius has more curvature which may be due to distortion in preservation). Anterior margin with only moderate curvature and transversely rounded edge. Pronator teres process reduced. Facet for humerus covers nearly all of proximal margin. Articular surface for carpal circular in outline and evenly concave. Capsular margin rounded, without posterior extension.

Ulna.—Complete right ulna exposed laterally with distal external surface revealed, slightly crushed and external border of semilunar (sigmoid) notch defaced; only internal half of shaft of left ulna exposed. Radial process massive with rugose surface. Olecranon process short anteroposteriorly and thickened transversely. Shaft stout with external surface convex in mid-region and flattened distally with posterior border broadly curving. Styloid process narrowly pointed extending approximately 26.0 mm. beyond shaft proper. Ulnar process reduced, rounded and gradually continuous with olecranon process and posterior border. Depression for external metacarpi pollicis in part obscured by extensive radial process, but shallow opposite semilunar notch. Area for extensor pollicis longus only a flat surface. Distinct narrow ridge separating the above two extensor areas. Semilunar notch and radial notch separated only by reduced ridge. Radial notch with shallow concave surface, wider than long.

Vertebrae.—Cervical vertebra: Atlas preserved ventrally, axis and cervical vertebrae (three through six) exposed in lateral and ventral view; seventh cervical not in line and twisted to mostly ventral view. Atlas: Relatively large size with wide neck and wide articular surface for condyle, transverse processes expanded laterally with border parallel to anteroposterior axis. Fossa atlantis unequal in size and elongate-oval. Axis: Long centrum. Tip of transverse process narrow and broadly expanded anteriorly, process projects perpendicularly from centrum with straight posterior edge. Prominent ventral median ridge. Foramen transversum nearly as wide as long. Third cervical: Much shorter than axis. Transverse process broken on anterior edge and with knob-like posterior extremity. Vertebrarterial canal elongate. Prezygophysis nearly parallel to centrum. Fourth cervical: As in third but transverse process bifurcate with blunt lamellae directed dorsolaterally. Anterior margin of lamellae thin. Fifth cervical: As in fourth but processes damaged. Sixth cervical: Inferior lamellar of transverse process much more developed posteriorly than in fifth cervical, with dorsal lamellar ascending abruptly dorsad. Seventh cervical: Like dorsals in absence of vertebrarterial canal and has a narrowly based, blunt end of transverse process. Dorsal vertebrae: All but first dorsal exposed in ventral view so that only centrum visible. Dorsals four, five and six covered by pectoral elements. First dorsal: Shorter than the seventh cervical. Oval facet for rib articulation on centrum and convex articular surface of transverse process with moderate, narrow, ventral median ridge. Second and third dorsal: Median ridge moderate. Seventh through fifteenth dorsals: Without ventral median ridge. Lumbar vertebrae: A portion of first lumbar present showing a short knob-like anterior ventral process.

Sternum.—Apparently presternum and seven sternal elements accounted for although some were slightly modified in preservation. First and second mesosternum in position near right humerus, third through seventh near distal end of radius and extending posteriorly, being mixed with phalangial elements. Presternum: Narrow-elongate element, anterior tip may be broken although this portion notably irregular in recent skeletons of Otariidae. Position of attachment of first rib near mid point of element. Ventral surface gently curved (convexly) and dorsal surface flattened (anteriorly at least). Anterior portion lance shaped with shallow concave lateral surfaces. Posterior shaft sharply convex

and distal end broadly expanded with moderately convex articular surface. Mesosternal bones: Actual shape not available except in first and second elements; but there is obvious distal expansion with concave articular surfaces. All sternal bones (except for markedly narrow first mesosternum) broader than long, indicating a strong protection for region of chest.

Ribs.—On left side, ninth through the fourteenth ribs are in natural positions except for actual articulation with respective dorsal vertebrae. Not certain that portions of the sixth, seventh and eighth ribs are present. On left side ribs have been dislodged to some extent. Effects of preservation have altered details of structure of ribs but they are in general characterized by roundness of cross section, particularly distal third and entire external surfaces, with slightly plain inner, posterior surface on remainder of shaft. Capitulum well developed, and with heavy, rounded extremity. Ribs as a whole are relatively heavy, sturdy structures serving, in addition to sternum, as additional substantial support for thoracic region.

Manus.—At first impression many elements of manus seem to be preserved; however only a few have actually retained distinct form and can be accurately measured. In preservation definite distinction between bone and rock has been lost or bones have been eroded away in part. Nonetheless, the general outline indicates the fossil bears the important family character of reduction of size of the digits from the first to the fifth.

Left manus with first metacarpal I, proximal phalanx and median phalanx definitely present and in general in position distal to radius; remainder of elements less certainly identifiable. Right manus with at least part of scapholunar and trapezium (though badly altered), metacarpal I and proximal phalanx I. Metacarpals tend to be rounded externally and one articular metacarpal surface (right II or III) is markedly convex in contour.

Phalanges show no definite tendency for flatness of the shafts on the internal surface of the manus. Modification for swimming, insofar as compression of elements is concerned, is not reliably determined.

The new species, *Atopotarus courseni*, presents a general picture of a medium sized eared seal with a large head, strong canines, elongate and strong neck, moderate-sized trunk, rather small but sturdy limbs, and true paddle-like feet. The animal may have been more agile on shore and less adept at swimming than its later relatives, although this is difficult to determine with the available evidence.

COMPARISONS

As is true of most all fossil pinnipeds, this specimen reveals many typical structures adapted to aquatic life. It is another record showing antiquity of the present day, basic pinniped morphology. It resembles the family Otariidae in characters outlined by Kellogg (1922) and Howell (1928) and is thus distinguished from the Odobenidae and Phocidae, on the basis of the following features: digits of manus decrease in size from first to fifth; skull with rudimentary postorbital process; mastoid process probably distinct from bulla (bulla not positively visible); angle of mandible inflected (though very slightly); scapula large, with relatively deep, high spine near posterior border, distinct acromion process and large prescapular fossa; humerus without entepicondylar foramen.

Comparisons with Fossil Otariids

Desmatophoca oregonensis Condon, 1906

The type specimen consists of a skull and partial mandible from the Miocene shales west of Newport, Lincoln County, Oregon, in the Astoria formation. Kellogg (1922, p. 107) gives the age of this species as upper Miocene—but in his geologic range chart he places it in upper middle Miocene. The mandible was kindly lent by Dr. Shotwell of the University of Oregon Museum. In addition, Dr. Shotwell took the necessary measurements of the type skull. The condition of the skull prohibited shipment for examination. *Desmatophoca* resembles *Atopotarus* as follows: great length of paraoccipital mastoid, reduced postorbital process, deep squamosal part of zygomatic arch (see Text-fig. 5), much constriction in postorbital area, absence of sagittal crest, shape of lambdoidal crest, and elongate snout. The mandible in *Desmatophoca* resembles *Atopotarus* in approximate thick-

ness and size (as can be judged from the portion represented, from M_1 anterior), a prominent genial tuberosity and double roots on the cheek teeth.

The type skull of *Desmatophoca* is particularly distinct from *Atopotarus* in the arched cranial profile, relatively small canine, greater depth of jugal (see Text-fig. 5), and wider zygomatic arch in anterior aspect. The mandible exhibits much closer spacing and greater size of cheek teeth, thicker ramus with more rounded ventral margin, relatively larger symphysis (anteroposterior diameter) with somewhat more rounded chin, more convex external surface, presence on ramus of shallow internal longitudinal groove (about 12.00 mm. dorsal to ventral margin), and smaller canine.

Packard (1947), described a humerus from the Astoria formation, Schooner Creek, Lincoln County, Oregon, and tentatively referred it to *Desmatophoca oregonensis* although he recognized that there are no comparable elements associated with the type. This humerus comes from near the type area and in many respects has characters similar to other known Miocene pinniped humeri. It is similar to *Atopotarus* in straightness of the shaft (lateral view), low and laterally compressed greater tuberosity, and narrow transverse diameter of the posterior margin.

Another smaller specimen, from the Astoria beds at Johnson Creek, 3.3 miles north of Schooner Creek, is probably referable to *Desmatophoca* (see Packard, 1947). It reveals reduction of the greater tuberosity as is seen in *Atopotarus*.

Through the kindness of Dr. Shotwell I have been privileged to examine specimen No. F 4100 from the University of Oregon Museum. The material was recently collected from the mouth of Spencer Creek near the type area of *Desmatophoca* and may prove to be this genus when detailed studies are completed. The matrix contains an upper canine, P^1 and P^2 and there are fragments of the posterior dorsal cranial region, and parts of the zygomatic arch, including the squamosal and posterior jugal. The specimen represents a young animal, differing from *Atopotarus* and showing possible resemblance to female *Zalophus* as follows: relatively greater depth of the jugal process; greater development of the saggital crest (a knife-like ridge with steep sloping sides). A marked resemblance to *Atopotarus* is the relatively large size of the canine.

Allodesmus kernensis Kellogg, 1922

This species is from the Miocene (middle or upper Temblor formation) near Bakersfield in Kern County, Calif. (Kellogg, 1922, 1931; Downs, 1953) and is now known from a number of specimens and most of the skeletal elements are available. The species is distinctive in many characters but there are some important resemblances to *Atopotarus* as indicated in the following features. Mandible: lack of inflection of angle, size of condyloid process, thickness and depth of the ramus, angle of the symphysis, flat internal and external surfaces, development of the genial tuberosity, shape and depth of the maseteric fossa, size of the lower canine. Scapula: angular coracovertebral margin. Humerus: straightness of the shaft, degree of development of the deltoid, size of the posterior trochlea. Radius: straightness and lack of great anteroposterior expansion of the shaft and angular proximal facet for the ulna and reduced distal dimensions. Ulna: curvature of the posterior margin. Sternal elements: general form (but marked distinction in the position of attachment of the first rib on the presternum).

Characters of *Allodesmus kernensis* which probably indicate generic distinction, from *Atopotarus courseni* are as follows: Skull: relatively smaller canine, marked backward curvature of lambdoidal crest with supraoccipital extending beyond occipital condyle. Mandible: presence of small M_2, more massive oval shape of symphysis, gradual ascent of coronoid, greater expansion of angle, more rounded chin and greater spacing between P_3, P_4 and M_1. Scapula: slightly greater length of neck, more elongate glenoid cavity, and prominent ridge extending upward from neck on prescapular fossa. Humerus: deltoid with more gradual ascent from shaft. Radius: relatively small size of proximal end, and more proximal position of the pronator teres process. Ulna: lesser width of radial process, poorly developed radial notch, flatter inner sur-

face of shaft. Vertebrae: atlas relatively larger, and has narrower transverse processes with margins more laterally directed; Presternum: shorter distance from posterior end to point of attachment of first rib.

Pithanotaria starri Kellogg, 1925

This species was described on the basis of an impression of a nearly complete skeleton from the upper Miocene, "Sarmatian," Celite mine near Lompoc, Santa Barbara County (not San Bernardino County as stated by Kellogg, 1925, p. 74). Kellogg points out relationship of *Pithanotaria* to *Callorhinus* and *Arctocephalus* but states that the skull is distinct from *Callorhinus* in greater depth of the braincase, greater arching of the cranial outline, and short and shallow rostrum. The same characters distinguish *Pithanotaria* from *Atopotarus*. The type of *Atopotarus* is also much larger than that of *Pithanotaria* (the skull in *Pithanotaria* is only 154 mm. long).

It is significant to note, however, that in *Pithanotaria*, as in *Allodesmus*, there are some apparent basic resemblances to *Atopotarus* in the post cranial skeleton (see discussion under *Allodesmus kernensis*). A referred specimen (Univ. Calif. Mus. Paleont. No. 26784) from the same locality as the type of *Pithanotaria*, is an impression of the left fore limb described by Kellogg (1925). The basic resemblances to *Atopotarus* pointed out above are duplicated in this material.

Neotherium mirum Kellogg, 1931

The known specimens of this species (calcaneum, astragalus, navicular, femori, humerus, third metatarsal and phalanges) were found in the same beds as *Alladesmus kernensis*. Generic distinction was established on the basis of characters of the tarsal bones. However the fragment of humerus, the only element which can be compared with both *Atopotarus* and *Allodesmus*, is like these genera in its thinness but distinctive in the lack of overlap of the deltoid.

Pontolis magnus True, 1905
(See also True, 1909)

The type skull of this species from the Pliocene of Coos Bay, Oregon is extremely large (length possibly 560 mm.) with a well-developed sagittal crest and deep jugal. These features readily distinguish it from *Atopotarus courseni;* but the relatively long paraoccipital-mastoid and backward projection of the lambdoidal crest resemble *Atopotarus*.

Lyon (1941) has shown the relationship of another nearly complete, though distorted skull, to *Pontolis magnus*. The material, including associated skeletal elements, is from the upper Miocene, Valmonte formation, Palos Verdes Hills, Near Lomita, Los Angeles County. The scapula resembles *Atopotarus* in the great anteroposterior diameter of the neck, and angular coracovertebral border and probable relatively large coronoid process.

Pliopedia pacifica Kellogg, 1921

This species, known from a number of incomplete bones including a humerus, radius, ulna, three metacarpals, two metatarsals, and three phalanges and recovered from upper Pliocene deposits in San Diego County, California, is easily distinguishable from *Atopotarus courseni* as follows: large size (over twice that of *A. courseni*), extreme distal width of the humerus (internal flaring), massive ulna, and rounded ulnar facet of the radius. However, the apparent straightness, slimness and posterior twist of the axis of the shaft of the humerus and the degree of curvature of the ulna suggest resemblance to *Atopotarus* and other Miocene pinnipeds.

Dusignathus santacruzensis Kellogg, 1927

The known specimens of this species from the upper Miocene of Santa Cruz, California, consist of a right and left mandible and posterior portions of the skull. It is particularly distinct from *Atopotarus* in: relatively large size of the mandibular cheek teeth, with small canine; short ramus and anterior massiveness combined with its sharp ascent posterior to M_1; the great size of the angular process and proximity to the condyloid process. There is some indication of resemblances to *Atopotarus* in the straightness and thinness of the posterior part of the ramus. There is at least superficial resemblance of the mandible to Recent *Otaria* of the southern hemisphere, al-

though the cheek teeth are relatively much larger in *Dusignathus*.

Zalophus and *Eumetopias*

Pliocene and Pleistocene representatives of these two genera are so similar to Recent forms, that comparisons are omitted here and the reader is referred to the section on Recent comparisons.

Unidentified specimens

Kellogg (1925, p. 95) describes two rib fragments from the upper Miocene beds near Lompoc. He was unable to identify them as other than otariid (?). Their significance lies in their heavy shafts—a feature noted in *Atopotarus*. They have flat surfaces, angular margins and short necks, characters that distinguish them from *Atopotarus*.

Comparisons with Recent Otariids

Of the Recent otariid genera, *Otaria*, *Eumetopias* and *Zalophus* show the greatest resemblance to *Atopotarus* in contrast to the possibly specialized *Callorhinus* and *Arctocephalus*. These conclusions are based on studies of male *Otaria*, female *Eumetopias* and male *Zalophus*. *Otaria* resembles *Atopotarus* in the shape and position of the lambdoidal crest in the skull but the greatest resemblance lies in the post cranial skeleton, evidenced as follows: reduced size of greater tuberosity, and slight curvature of shaft of the humerus; shape of neck and coracovertebral angle in scapula; position and development of ridge separating depression for the extensor pollicis longus and extensor metacarpi pollicis, and curvature of shaft (lateral view) in the ulna; curvature of shaft, shape of anterior margin, and position of pronator teres process in the radius; wide transverse processes of atlas and rounded surfaces of ribs (sternal elements were not available in the *Otaria* material borrowed). The massiveness of the mandible and relatively large size of the lower canine are striking characters that distinguish *Otaria* from *Atopotarus*. The genera *Zalophus* and *Eumetopias* do not show as great a resemblance to *Atopotarus* in the above features. However, the skull in *Eumetopias* is more like *Atopotarus* than is *Otaria* in the position of the mastoid posterior to the glenoid cavity and in the general shape of the mandible.

As indicated in Text-fig. 5, *Otaria* and *Eumetopias* have relatively shorter necks and longer limbs than *Atopotarus*. *Zalophus* is somewhat more like *Atopotarus* in these proportions. *Zalophus* also shows greater resemblance to *Atopotarus* in some other features of the post axial skeleton than does *Eumetopias;* for example, the slight curvature of the shaft in the humerus and ulna, the angular shape of the coracovertebral angle in the scapula and the great length of the axis. Considering the hundred or so features of the skeleton as a whole, male *Otaria*, the southern hemisphere eared seal, shows somewhat greater resemblance to *Atopotarus* than does male *Zalophus*.

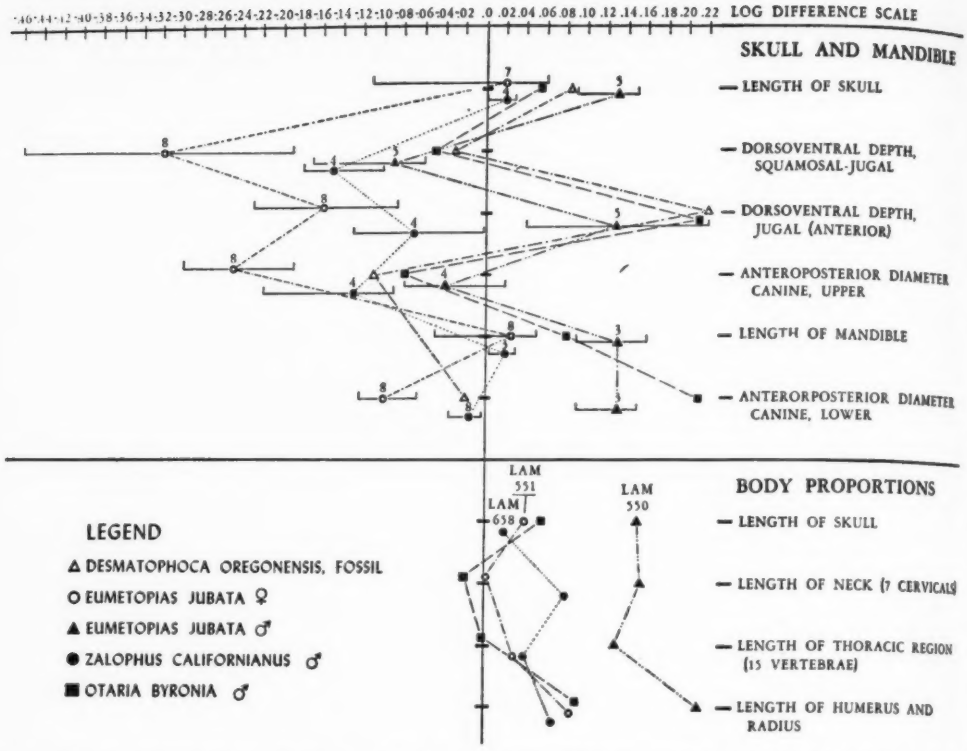
AGE RELATIONSHIPS

The new genus is related to the *Allodesmus kernensis* Kellogg which has recently been dated as "probably no later than late middle Miocene or possible transitional between middle and late Miocene age," (Downs, 1953). Although *Allodesmus* and *Atopotarus* agree in many characters of the postcranial skeleton (see under 3 phyletic relationships, below), the evidence of additional, possible archaic characteristics of the skull and mandible in *Allodesmus*, suggests that *Allodesmus* might be more "primitive" than *Atopotarus*.

Woodring, Bramlette & Kew (1946), on the basis of work by Kleinpell on Foraminifera, have considered the middle part of the Altamira as late middle Miocene age and correlated it with the Modelo formation in the Santa Monica Mountains. Certainly the combined evidence of morphology, geology and faunal correlations indicate Miocene age for *Atopotarus* and there is no evidence for considering the genus lower or early middle Miocene age. *Allodesmus* could have lived at the same time as *Atopotarus*, carrying on as a surviving "archaic" type. The two genera are not far apart in their geologic age and we can only conclude that *Atopotarus* lived during the late middle Miocene or early upper Miocene.

GENERAL DISCUSSION

Remarks on the taxonomy.—Study of variations in size and morphology due to


LOG DIFFERENCE SCALE
SKULL AND MANDIBLE
— LENGTH OF SKULL
— DORSOVENTRAL DEPTH, SQUAMOSAL-JUGAL
— DORSOVENTRAL DEPTH, JUGAL (ANTERIOR)
— ANTEROPOSTERIOR DIAMETER CANINE, UPPER
— LENGTH OF MANDIBLE
— ANTERORPOSTERIOR DIAMETER CANINE, LOWER
LEGEND
△ DESMATOPHOCA OREGONENSIS, FOSSIL
○ EUMETOPIAS JUBATA ♀
▲ EUMETOPIAS JUBATA ♂
● ZALOPHUS CALIFORNIANUS ♂
■ OTARIA BYRONIA ♂
LAM 551 / LAM 658
LAM 550
BODY PROPORTIONS
— LENGTH OF SKULL
— LENGTH OF NECK (7 CERVICALS)
— LENGTH OF THORACIC REGION (15 VERTEBRAE)
— LENGTH OF HUMERUS AND RADIUS

TEXT-FIG. 5—Comparisons of skull, mandible and body proportions in Recent and fossil otariids. A ratio diagram with the new genus *Atopotarus* represented at .0 point. All measurements of other species larger than *Atopotarus* fall to the right of this .0 point, all smaller measurements fall to the left. The horizontal bars represent the extremes of measurement and the symbols for respective genera are located at the mean point of the distributions. Measurements are reduced to difference in their logarithms. Numerical notations refer to number of available specimens of skulls and mandibles for study.

growth stages and sexual differences in Recent pinnipeds (see Text-fig. 5; Hamilton, 1934, 1939; Sivertsen, 1954) indicates that supposedly generic distinctions in the extinct fossil forms must be evaluated as to a possible reflection of purely individual or sexual differences. In the comparison of Recent male and female *Eumetopias* the distinction between the sexes in the post-cranial skeleton is a matter of degree of difference in size. The greatest sexual differences lie in the skull and mandible; for example, in the male *Eumetopias*, the development of the sagittal crest, the deeper zygomatic arch and the great massiveness and depth of the jaw as compared to that in female *Eumetopias*. However, young males and adult females show great resemblance to each other and intergradation of characters occur. The new genus *Atopotarus* exhibits a total complex of diagnostic traits in both cranial and postcranial regions of the skeleton. Such an accumulation of diversified characters adds weight to the conclusion that the genus is valid. It has been convincingly shown by Kellogg that the genera *Allodesmus* and *Pithanotaria* likewise exhibit many diagnostic traits in cranial and post-cranial regions. It is my opinion that all but three of the genera of fossil and Recent Otariidae (following Simpson, 1945) are based on nearly equally significant diagnostic characters and that the distinctions are, for the present, best expressed as generic differences. This is true of the genera *Allodesmus*, *Atopotarus*, *Dusignathus*, *Pithanotaria*, *Pontolis*, *Callorhinus*, *Arctocephalus*, *Eumetopias*, *Zalo-*

phus and *Otaria*. *Desmatophoca*, *Pliopedia* and *Neotherium* are for the present too poorly known for adequate judgement, although present evidence seems to indicate that *Desmatophoca* and *Pliopedia* are probably distinctive and *Neotherium* may possibly be definitive. Sivertsen (1954), recognizes two other Recent genera, *Neophoca* Gray from Australia and New Zealand and *Arctophoca* Peters from Juan Fernandez-Mas a Fuera and Guadalupe Is. *Neophoca* is shown by Sivertsen to be highly variable and its generic distinction seems questionable to me although I have not seen the specimens. *Arctophoca* is represented by only five specimens, yet Sivertsen presents good evidence that the genus may be distinctive—especially as shown in the narrowness of the skull and palate. The collection of more representative material would assist in obtaining a better understanding of these two genera.

Function and structure.—In the present study it is impractical to analyze and determine the definite relationship between musculature, osteology and function in *Atopotarus courseni*. However, thanks to the thorough work of Howell (1928), it is possible to contemplate relationships based on his summary of the study of Recent otariids (*Zalophus*) and phocids (*Phoca*). The forward slope of the occipital crest (and lambdoidal crest) in the skull of *Atopotarus* is characteristic of pinnipeds and cetacea. *Atopotarus* possesses a long and strong neck with well developed atlas and axis, as is also true of Recent otariids. In Recent otariids the head and neck are very mobile and play an important part in their peculiar terrestrial locomotion; the neck sways back and forth with the motion of the fore limbs and also allows darting, sinuous movements under water in search of prey. Morphologic resemblance of *Atopotarus* to Recent genera in the neck and head structure suggests possible similar functional resemblance also. *Atopotarus* had simple molar teeth, like modern sea lions—but unusually strong canines—thus suggesting that it was well equipped for defensive action.

The limbs of *Atopotarus* are relatively short and sturdy but not massive in their individual elements. The limbs of other Miocene genera vary in their lengths but they are likewise not massive in form. Howell (1928, p. 116) states that in Recent otariids the great height and massiveness of the greater tuberosity of the humerus is "for supplying increased leverage to the large supraspinatus which helps extend the humerus"—a recovery movement after the backward sweep of the fore flipper. In addition, the enormous development of the deltoid allows important leverage to a short bone, providing for strong rotation. Both of these features are not as strongly indicated in Miocene genera as they are in Recent otariids. In addition, the Miocene genera had a relatively narrow radius (unlike the typical broad, paddle-like structure in Recent otariids) and a shallow ulna (anteroposterior diameter) contrasted with the deep proximal end of this element in Recent genera. The characters of the humerus, radius and ulna of Recent otariids reflect the particular specialized swimming habits of these animals and in turn a much greater use of the fore limb for swimming than in the phocids. It has been shown that these features are only moderately developed in Miocene otariid genera thus suggesting a less special adaptation of the fore limb (or possibly a different adaptation) as compared with Recent otariids.

Paradoxically, however, it is interesting to note that in the three Miocene forms in which the scapula is present, it is characterized by extreme development of the prescapular fossa, the area for the insertion of an apparently large supraspinatus muscle (as noted above, the opposite condition of the supraspinatus is suggested in the structure of the humerus).

Phyletic relationships.—The study of the history of pinnipeds is still at the descriptive level (the alpha level of Mayr, Linsley & Usinger, 1953, p. 19), and consequently conclusions on problems of evolution in the order are tentative. We do know, however, that in the Otariidae certain traits are found to be common to many of the early fossil genera although some traits are markedly distinctive in each. It has been possible to plot the occurrence of characters present in known fossils materials, assigned to the Miocene genera *Allodesmus*, *Atopotarus*, *Neotherium*, *Desmatophoca* (type), *Desmato-*

phoca? from Schooner Creek, cf. *Allodesmus* from Aliso Creek (Downs, 1955), *Pithanotaria*, and the large seal from Lomita, California (Lyon, 1941).

In this material the following characters are notably common to all (where comparable elements are available):

(1) Mandible straight and with slim-elongate shape of horizontal ramus. (2) Scapula with angular coracovertebral margin and wide neck (anteroposteriorly, lateral view). (3) Humerus with gentle curvature of shaft, greater tuberosity reduced or not extending beyond head; angle of head axis relative to shaft axis large (30–40°); moderate overhang of deltoid crest; and slimness of the shaft. (4) Radius with straight and narrow anteroposterior diameter of the shaft. (5) Ulna with gently curving, stout, rounded shaft.

Other characters such as presence of an M_2; narrow posterior trochlea of the humerus; angular facet for the ulna in the radius; broad transverse processes of the atlas; and rounded, heavy ribs, may be significant as common to Miocene otariids but their substantiation as such is hampered at present by the condition of the available material. In the fossil record there are more humeri than other elements available for comparisons; consequently greater verification of common characters is at hand in this element. *Otaria* and *Zalophus* reflect in their postcranial skeletons, more of the Miocene traits than does *Eumetopias*. This supports Kellogg's contention (1922) that *Zalophus* may be more generalized than *Eumetopias;* he did not discuss the relationship of *Otaria*.

The following features represent "advanced" or chronologically later development in the family and are clearly exemplified in the Recent *Eumetopias*. (1) Marked inflection of the angle of the mandible; (2) great thickness of the mandible and marked ventral curvature; (3) single roots on the cheek teeth and absence of M_2; (4) gently rounded coracovertebral margin and narrow neck of the scapula; (5) extreme curvature and relative shortness of the shaft of the humerus, with large greater tuberosity projecting well beyond the head of the humerus, and massive overhang of the deltoid crest; (6) laterally broad proximal ulna with strong backward curvature; (7) flat and curving radius.

The present fossil record gives no evidence of a particular trend in size or morphological development in the otariids. In the Miocene there are small, large and moderate-sized sea lions described. All of these exhibit, in the parts available for comparison, the basic pinniped form in the paddle-like limbs and toes and simple peg-like teeth. But no one Tertiary genus can be considered more closely related to a Recent form than another. Present knowledge indicates that there may have been as many adaptive phases of the family Otariidae during the Tertiary as there are today. In the middle and late Miocene alone there are seven described genera of otariids; there are at least five easily recognized genera living today (see Simpson, 1945).

It has been emphasized to me in recent discussion with J. A. Shotwell, that the otariids may represent a group that arose through quantum evolution or evolution defined as . . . "the relatively rapid shift of a biotic population in disequilibrium to an equilibrium distinctly unlike an ancestral condition" (Simpson, 1944, p. 206). There might be little chance of finding the remains of such a population in the fossil record. But one may ask: do we have a representative fossil record of the otariids or is there some nonbiological circumstance of the geologic record that forbids the finding of otariids in earlier rocks? There are no positively established records of otariids prior to the Miocene; yet they appear to be relatively common during and after that epoch. It may be noted, however, that there are many exposed rocks of marine origin along the Pacific coast and other parts of the world that contain Eocene and Oligocene invertebrates and cetaceans. These rocks surely could have contained otariids if they were amply represented in the marine waters. Cetaceans and pinnipeds are relatively common in Miocene marine rocks. The cetaceans of the Eocene and Oligocene ages were not uncommon and were basically whale-like in structure; the order must have had an ancient origin although the record has not shown the complete story of their probable derivation from land mammals (Kellogg, 1928). Their history or mode of evolution is

apparently paralleled in the Otariidae, although the change from one adaptive zone to another may have occurred at different times in the history of the two groups. The original population of land carnivores from which the pinnipeds were probably derived must have been small or rare, geographically restricted, genetically variable, preadaptively suited, and receptive to effective selection in order for them to cross the "threshold" and enter the new, aquatic, adaptive zone. The possibility that the original transitional forms were members of small and rare populations (fresh or marine water inhabitants) may explain the lack of fossil evidence. As Simpson (1953) and others acquainted with fossil records of vertebrates have noted, the fact we have as good a fossil record as we do is very remarkable when we consider the odds against vertebrate remains being buried, fossilized, preserved, then exposed on dry land and finally discovered by a paleontologist. It is believed, therefore, that the record of the Otariidae that we know today is probably as representative as most fossil records, and is best explained by application of the quantum theory of evolution.

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A CHADRON MAMMALIAN FAUNA FROM NEBRASKA[1]

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ABSTRACT—A small mammalian fauna from Chadron strata near Orella, Nebraska, is described. The specimens were collected from several levels, all very near the basal conglomerate which marks the Pierre-Chadron contact. The fauna includes a number of brontothere skulls, seemingly of typical middle Chadron genera, a sampling of other lower Oligocene mammals and several rodent jaws. One of these is new (*Cylindrodon nebraskensis*), a cylindrodont very similar to the Pipestone Springs species, *Cylindrodon fontis* Douglass. The presence of *Cylindrodon*, known heretofore only from the lower Chadron, and the stratigraphic position suggests a lower Chadron age, although perhaps not the exact time equivalent of the deposits at Pipestone Springs, Montana.

DESCRIPTION OF THE LOCALITY

IN 1950 Raymond Alf and a party of students from the Webb School, Claremont, California, collected a number of vertebrate fossils from Chadron strata near Orella, Nebraska. The fauna found in place, although small, is an interesting one because it includes a number of brontothere skulls, a skeleton of *Hoplophoneus*, a very good sampling of the usual mammals from the White River and three rodent jaws, one of which is a cylindrodont near the species from Pipestone Springs, *Cylindrodon fontis*.

The Nebraska specimens were collected from the NW corner of the SE ¼ sec. 5, T. 33 N., R. 53 W., Sioux County. The exposures here are relatively thin, about 80 feet. The base is marked by a basal conglomerate resting on the weathered surface of the Pierre. The top is characterized by the upper purple-white layer, a continuous purple-tinted white limestone designated by Schultz and Stout (1938) as the boundary between the Chadron and the Brule formations of the White River group in this area. About halfway between this and the basal conglomerate there is a second limestone lens which will be designated in this paper as the lower purple-white layer.

All of the fossils come from well below the lower purple-white layer. The position of the titanotheres in one measured section is approximately 30 feet below this purple-white layer. This brings them very close to the basal conglomerate marking the contact with the Pierre. All of the other specimens were found near this level except the *Hoplophoneus* skeleton which was somewhat higher, about 10 feet below the lower purple-white layer.

This position with relation to the Pierre-Chadron contact, would seem to place the fauna as lower Chadron in age. The relative thinness of the Chadron at this locality, however, suggests that there might have been a period of erosion—or at any rate nondeposition—during earliest Chadron time. The presence of *Cylindrodon* and *Titanotheriomys* in the fauna suggests a comparison with the fauna at Pipestone Springs, Montana, usually considered to be of very early Chadron age. Other elements of the fauna, i.e., the titanothere and horse specimens which are comparable to those of the middle and upper Chadron of South Dakota, indicate a higher position in the Chadron, at any rate according to present interpretation.

AN INTERESTING ANT HILL FAUNA

Recently, 1952–1953, another party conducted by Mr. Alf made an extensive search of the ant hills in the vicinity of the Chadron outcrops near Orella. A very large number of specimens of small jaw fragments and teeth were obtained. These are under study by Mr. Alf and others. Those so far identified include *Pelycomys* (24 teeth), *Heliscomys* (26 teeth), *Eumys* (267 teeth), including those of *Eumys elegans*, *E. exiguus* and *E. planifrons*. These genera have to date been reported only form middle or upper Oligocene strata. The abundance of these

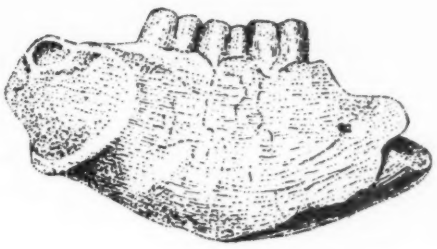
[1] Publication authorized by the Director, U. S. Geological Survey.

forms in Chadron deposits suggests that their range may be greater than supposed and that their absence from other Chadron beds may be due to accidents of collecting or preservation. It is possible, of course, that the ant hill specimens were concentrated by the ants from a wider vertical range than that represented by the specimens which were found in place

A preliminary list of the ant hill fauna is here given to afford further comparison.

Faunal list from ant hill in the Chadron formation (Identification by R. Alf, R. Wilson, E. C. Galbreath and others):

Class Mammalia
- Order Marsupialia (5)
  - *Nanodelphys*
- Order Insectivora (182 teeth)
  - *Domnina*
  - *Ictops*
  - *Metacodon*
  - *Apternodus*
  - Several others—*Proterix*?, *Clinodon*?, *Proscalops*?
- Order Primates (5 teeth)
  - *Sinclairella*
  - Another form either primate or insectivore
- Order Rodentia
  - Family Ischyromyidae
    - *Prosciurus* (78 teeth)
    - *Pelycomys* (24 teeth)
    - *Ischyromys* (81 teeth)
    - *Cylindrodon* (25 teeth)
  - Family Eutypomyidae
    - *Eutypomys*?
  - Family Eomyidae (168 teeth)
    - *Adjidaumo*
    - *Paradjidaumo*
    - One new genus and probably another
  - Family Heteromyidae
    - *Heliscomys* (26 teeth)
    - *Proheteromys*-like (2 teeth)
  - Family Geomyidae
    - *Diplolophus*-like
  - Family Cricitidae (267 teeth)
    - *Eumys*, including *E. elegans*, *E. exiguus*, *E. planidens*
- Order Lagomorpha (800 teeth)
  - *Paleolagus*
  - *Megalagus*
- Order Artiodactyla (19 teeth)
  - *Leptomeryx*
  - *Hypisodus*



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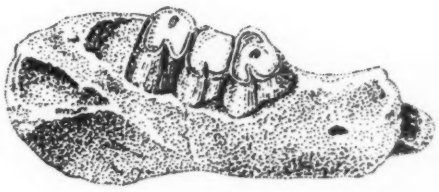

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TEXT-FIG. *1,2—Cylindrodon nebraskensis*, n. sp., holotype, Webb School Museum No. 1908, right ramus of lower jaw, lateral and crown views.

- Order Carnivora (28 teeth)
  - Several types not yet determined.

SYSTEMATIC DESCRIPTION OF THE SPECIMENS FOUND IN PLACE

Order RODENTIA

Family CYLINDRODONTIDAE

CYLINDRODON NEBRASKENSIS, n. sp.

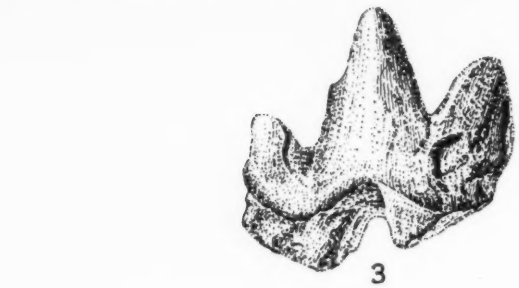
Text-figs. 1, 2

Holotype.—Webb School Museum No. 108 Right ramus of lower jaw with P_4 M_2 and alveolus of M_3.

Locality.—Near Orella, Nebraska, northwest corner of SE ¼ sec. 5, T. 33 N., R. 53 W., Sioux County, Nebraska.

Horizon.—Chadron

Diagnosis.—As large as the largest specimens of *C. fontis* from Pipestone Springs, Montana, but with the ramus of the jaw deeper, shorter, and more massive. One large mental foramen situated well foward. Masseteric fossa somewhat concave, bounded anteriorly by a raised rim. Teeth in state of wear in which only the median fossette is present in P_4 and M_2, and the pattern is entirely obliterated on M_1. Molars quadrate in outline, transverse diameter greater than anteroposterior



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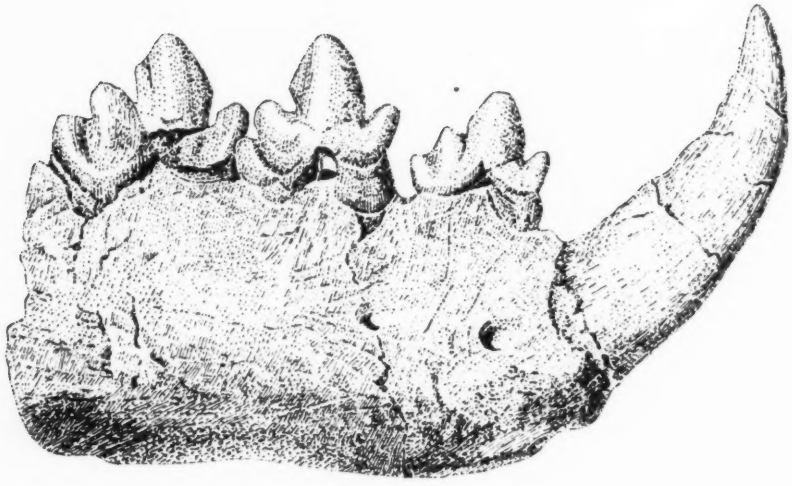

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TEXT-FIG. *3*—cf. *Pseudaelurus* sp., M_1, lateral view.
4—cf. *Pseudaelurus* sp., right ramus of lower jaw with dP_2, P_3, P_4.

diameter; hypoconids broad, extended laterally with little recurvature.

Discussion.—Only one species of *Cylindrodon* has hitherto been named. This is the type of the genus *C. fontis* Matthew from the lower Oligocene of Pipestone Springs, Montana. Wood (1937) describes specimens from the Cypress Hills of Saskatchewan, Canada, and from the Oligocene of Beaver Divide, Wyoming. He terms the latter specimens *Cylindrodon*, n. sp., but does not name the species. This specimen seems to resemble the Beaver Divide jaws more than those from Pipestone Springs particularly in the more quadrate form of the molars when worn and the broad, flat incisors. The teeth are relatively narrower, however, the mental foramen more anteriorly placed and the fossa behind the symphysis less deeply excavated. Probably there was considerable individual variation in cylindrodonts as well as regional differences of specific or subspecific rank.

Family ISCHYROMYIDAE

ISCHYROMYS PLIACUS Troxell

Two right lower jaws in this collection are within the size range of this species which is the largest of the genus. It ranges throughout the Oligocene.

TITANOTHERIOMYS cf. T. WYOMINGENSIS (Wood)

This genus, which is usually considered exclusively lower Oligocene, is represented by a maxillary with P^4–M^3. The specimen is considerably larger than the type of *T. veterior* and seems similar to the specimens from Beaver Divide referred by Wood to *T. wyomingensis.*

Order CARNIVORA
Family FELIDAE
cf. PSEUDAELURUS sp.
Text-figs. 3, 4

The anterior portion of a lower jaw bearing the canine and three premolars presents somewhat of a problem in identification. There is no Oligocene carnivore known to the writer which resembles it at all closely in size or in the number and construction of the premolars. The three present (P_2, P_3, P_4, or if they are milk teeth as is probably the case, dP_2, dP_3 and dP_4) all have anterior and posterior cusps flanking a high, compressed median cusp. In addition there is an accessory basal cusp derived from the posterior cingulum. The construction of the teeth is not unlike that of *Pseudaelurus marshi* Thorpe (Thorpe, 1922, fig. 12) but the median cusp is higher and more sharply separated from the anterior and posterior basal cusps. Moreover, P_2 is a fully formed tooth very similar to P_3 whereas in *Pseudaelurus* this tooth is reduced to peg-like proportions or absent altogether. These facts suggest that the jaw may be an immature one with a milk dentition. It may belong to one of the known Oligocene felids, *Nimravus* or *Dinictis*, or may represent an early pseudaelurine. The specimen is here figured and a detailed description given in order to facilitate further comparisons, but the material seems insufficient to be the basis of a new genus or species.

Description of jaw.—The jaw is robust, about the size of that of *Dinictis squalidens* but without any trace of a flange. It does not taper anteriorly, the depth below dP_2 being almost as great as that below dP_4.

The teeth are unworn. The canine is oval in cross section with a sharp but unserrated cutting edge along the posterior face. It is a pointed, recurved and relatively short tooth which appears longer in the specimen because a part of the jaw is broken away at the base. Just posterior of the base of the canine there is a small alveolus in which a point of a tooth is showing. This is interpreted as being the alveolus of the permanent P_2. The first milk premolar, dP_2 is smaller than the other premolars but two rooted. The median blade is low compared to that of the succeeding teeth, and compressed laterally. Distinct anterior and posterior cusps are present as well as a small posterior cingular cusp. The third premolar has the same construction but the median blade is higher and sharper. The anterior and posterior cusps are somewhat higher and broader, the posterior cingular cusp more pronounced. In dP_4 the median cusp is broader, the posterior cusp lower and more sharply separated from the median cusp by a notch. The posterior cusp which is higher and more closely appressed to the median cusp forms a distinct heel bounded by a crest.

A detached M_1 and small M_2 are associated with the jaw. The carnassial has a high anterior cusp of the usual feline shape and a high trenchant median cusp separated from the anterior cusp by a deep notch. (The notch appears deeper and the median blade slenderer than it actually was because part of the anterior face of the median cusp is broken.) A small metaconid is present on the postero-internal face of the median cusp. The talonid is a low sharp cusp separated from the median cusp by a broad notch. M_2 is very small but has a distinct median cusp and a low anterior cingular cusp connected with it by ridge. There is a low but distinct talonid.

DINICTIS sp.

A fragment of upper dentition with a broken carnassial is the only specimen in the collection referable to this genus.

HOPLOPHONEUS MENTALIS Sinclair

This rare species is represented in the collection by an almost complete skeleton. Unfortunately the only remains of the skull are the right half of the facial region, a portion of the nasal bone and a piece of the zygomatic arch. The teeth are either missing or broken at the roots. The lower jaw consists of only a fragment with broken teeth.

It is apparent, however from the alveolus and root of the upper canine that the species is *H. mentalis*. The facial region is short, in this respect more like the specimen in the South Dakota School of Mines than the one in the University of Colorado Museum at Boulder. Almost no other comparison can be made because of the incompleteness of the skull and jaw. The skeleton presents no significant difference from the other known

specimens. The measurements in millimeters are given below.

	Drepanodon charri (Jepsen)	Webb School specimen
Diastema behind c	18	11.4
Upper canine, ant.-post. diam.	22	22
Upper canine, transverse diam.	9.0	7.5
Tooth-row, c to ml incl.	79	74
Humerus, width of prox. end		
Ulna, legth fr. olecranon	180	183
Ulna, width, prox.	22	21.7
Ulna, width, dist.	22	20.4
Femur, length fr. gr't troch	195	212
Femur, width, prox.	51	44?
Femur, width, dist.	43	38.8
Tibia, internal length	151	170
Tibia, width, prox.	43	45?
Tibia, width, dist.	25	27.3
Calcaneum, length	54	52.5
Calcaneum, width over sustent	23	29?
Calcaneum, width of dist. end	17	18
Astragalus, length	31	32.5
Astragalus, width of trochlea	18	17
Metatarsal I, length	27	
Metatarsal II, length	40	43.6
Metatarsal III, length	33	48.5?
Metatarsal IV, length	48	53.0?
Metatarsal V, length	37	49.0?
Digit III, Phal 1, length	22	25?

Family CANIDAE

PSEUDOCYNODICTIS near P. PATERCULUS (Matthew)

Pseudocynodictis is represented in this collection by a portion of the maxillary with P^4–M^3, and several lower jaw fragments which among them include all of the lower cheek teeth. From Galbreath's description of the lower jaws in the Horsetail Creek collection which he also considered near *P. paterculus* (Galbreath, 1953, p. 75) these are closely similar and probably conspecific. The type of *P. paterculus* is a lower jaw. A referred specimen U.S.N.M. 18911, which includes a skull, jaws and partial skeleton collected by T. E. White from the lower Oligocene of Canyon Ferry, Montana, will be used for comparison.

Upper dentition.—The Nebraska specimen is larger than *P. paterculus* as represented by the National Museum specimen referred to above. The upper cheek tooth formula is the same, a small M^3 being present in both specimens. P^3 in the Nebraska specimen is proportionally larger but has essentially the same structure, i.e., a high sharp median cusp, lower anterior basal cingulum with no cusp, a pronounced posterior basal cingulum developed into a low cuspule and with an accessory cusp between it and the median cusp. P^4 has about the same shape in both specimens with an oblique shear and the anteroexternal margin of the crown amost on a line with the anterior margin of the deuterocone. The tooth in the Nebraska specimen, however, is larger proportionally than in *P. paterculus*. The anteroposterior diameter measured along the external border is 10 mm., the anteroposterior diameter of M^1 plus M^2 is 9 mm. In U.S.N.M. 18911 the anteroposterior diameter of P^4 is 8 mm., that of M^1 plus M^2 is 8 mm. The pattern of M^1 in both specimens is very similar although the cusps in *P. paterculus* seem somewhat higher. In both specimens this tooth is asymmetrical and marked by a pronounced development of the external cingulum which is extended anteriorly to form a low parastyle. This gives the tooth a "miacid" rather than "canid" appearance. The paracone and metacone are high in both the Nebraska specimens and U.S.N.M. 18911 and close together, also primitive features. The protocone is single and crescent shaped. The internal cingulum is broad and produced into a crest. It is asymmetrical, the posterior portion being much more developed than the anterior which only forms a faint rim around the tooth. M^2 in the Nebraska specimen is a miniature of M^1. This is a little less true in U.S.N.M. 18911 because the tooth is smaller and narrower with less distinct cusps. M^2 is a nubbin in both specimens but is considerably smaller in the specimen referred to *P. paterculus*.

Lower jaw and dentition.—The lower jaw of the Nebraska specimen is larger and more robust. The cheek teeth are larger proportionally, less obliquely set in the jaw, and without the slight backward extension noticeable in *P. paterculus*. M^1 is larger proportionally as would be expected from the upper dentition. The cusps are somewhat

blunter—otherwise the tooth is similar in the two specimens. The cusps of M^2 seem somewhat lower, and M^3, judging from the alveolus, was longer (it is, however, very minute in both specimens).

Status of Pseudocynodictis paterculus.—*Pseudocynodictis paterculus* was based by Matthew on two lower jaws (AMNH 9616, 9619) and parts of others from Pipestone Springs, Montana. The distinction from *P. gregarius*, based largely on the construction of M_2, was admitted to be slight, but from the material at hand Matthew thought the differences constant. With this the writer cannot agree. Study of a large number of specimens, including skulls with jaws attached, and numerous lower jaws and jaw fragments from the Brule of Niobrara Co., Wyoming, as well as the half dozen lower jaws from the deposits at Pipestone Springs in the National Museum collection, show that the characters described by Matthew are highly variable and that the differences, such as the length of M_2, height of the paraconid, protoconid, and metaconid are so slight that no two people studying the same series of jaws would classify them the same way.

Moreover, *P. paterculus*, when all characters of the skull and dentition are taken into consideration, grades into *P. gregarius*. This is not so evident if only the larger skulls assigned to that species are considered, but there are, in fact, two or perhaps three groups frequently included. One of these, usually of large size and with notably long narrow skulls and very forwardly placed postorbital constriction, probably should be referred to *P. lippicotianus* (Marsh). The other more "typical" *P. gregarius* includes medium- to small-sized skulls, broad, with a marked, posteriorly placed postorbital constriction. The small skulls are barely distinguishable from *P. paterculus* either in skull or dental characters. This is especially true when such intermediates as the Nebraska specimen just described are considered. The writer believes that a redefinition of *P. paterculus* will include these specimens in the species. Thorpe in fact suggested something of the sort in his description of the Marsh specimens (Thorpe, 1922, p. 428). A more adequate treatment of the problem is planned for a future paper.

Pseudocynodictis paterculus, however, as presently defined also includes some very small forms, as yet represented only by lower jaws and maxillary portions. These are very much smaller than the smallest specimens of *P. gregarius*. The dental differences also are very much more marked. These are probably either a new species, or should be referred to *Procynodictis vulcipes*, which they closely resemble.

Order Artiodactyla
Family Choeropotamidae

Two molars, M_2 and M_3 in a jaw fragment, have a tooth pattern resembling that of *Achaenodon* but the jaw is smaller, the size relative to that of the teeth, more resembling that of the lower Eocene *Parahyus*. The writer knows of no Oligocene Artiodactyla of such small size which have this type of tooth. The jaw fragment may possibly belong to *Brachyhyops*, a genus of the same family described by Colbert (1938) on a skull only, collected from the channel fill (lowermost Oligocene) of the Beaver Divide.

Family Suidae
Perchoerus probus ?

There is a single upper molar of *Perchoerus* in the collection. It is a large size, the greatest anteroposterior diameter being 24 mm., the least 18 mm. These dimensions are much greater than those of the described Chadron species, *P. minor* and *P. nanus*.

Family Anthracotheriidae
Bothriodon sp.

This genus is represented by an upper dentition consisting of M^1–M^3. The distinction between the Chadron and Brule species is largely based on skull characters. The cheek teeth of the two are so similar that the two species cannot be separated on that basis. In this case, the only character of the molars supposed to be distinctive, i.e., the width of the median valley, appears to resemble the Brule species, *B. rostralis*, more closely than the Chadron species *B. americanus*.

Family Merycoidodontidae
Merycoidodon culbertsoni Leidy

A skull and numerous fragments of lower jaws belong either to this species or *M.*

gracilis (Leidy). They are somewhat large for the size range of the latter but are small individuals of the former. The skull definitely does not belong to any of the typical early Chadron genera (*Limnenetes* or *Oreonetes*) and it is too small for *Merycoidodon affinis*.

Family Camelidae
Poebrotherium sp.

Several portions of lower jaws belong in this genus, which is usually considered to be equivalent in age to the Orella member of Schultz & Stout (1938).

Family Hypertragulidae
Leptomeryx evansi Leidy
and
Leptomeryx esulcatus Cope

There are numerous lower jaws and lower jaw fragments in the collection. The range in size is considerable and the smallest specimens may be the same as the small form described by Galbreath from the Horsetail Creek fauna (Galbreath, 1953, p. 90). *Leptomeryx esulcatus* is usually considered the Chadron species, and *L. evansi* characteristic of the Brule. The distinction between the two, which is based only on the structure of P_3, is impossible to apply to many jaws or fragments of jaws which do not have P_3. At least one specimen in this collection, however, is *L. esulcatus*, if that distinction is valid, and one, an unusually large jaw, is *L. evansi*.

Order Perissodactyla
Family Brontotheriidae
Brontops dispar Osborn?
Brontops near B. brachycephalus (Osborn)
Brontops sp.

Brontothere remains are abundant throughout the lower levels of the deposits. The three skulls mounted in the Webb School Museum are probably all *Brontops*. The species is less certain. One skull in immature, and one seems fairly close to *Brontops dispar*, and another is similar in most characters to the skull from the Cypress Hills formation of Saskatchewan referred by Russell (1940, p. 91, pl. 1) to *Brontops brachycephalus*. A lower jaw appears to be a different genus and perhaps is *Megacerops*. Measurements are given in the accompanying table.

Among the specimens there is an articulated left front leg. This is unusual in having a trapezium, a condition unknown among other Chadron brontotheres. In general, however, the titanotheres appear to be forms of Chadron age. *Teleodus* is not represented.

Family Hyracodontidae
Hyracodon nebraskensis? Leidy

This specimen consists of an upper milk dentition. Comparison with milk dentitions of *H. nebraskensis* in the National Museum collections does not disclose any important distinction.

Measurements of *Brontops* Skulls and Jaws, in Millimeters

(All specimens are from Webb School Museum, Claremont, California)

	A	B	C	D	E	F	G	H	I	J
Skulls										
Basilar length (pmx-cond)	680	710	760	655	745					
Zygomatic width	570	380	545	395						
P^1–M^2	325	325	367	342	352					
P^1–P^4	113	113	133	117	127					
M^1–M^3	212	212	234	225	225					
Nasal length	68	82		100	57					
Horn length	127	118	152	63	152					
Jaws										
P_1–M_3	330	330				334	390	355	392	357
P_1–P_4	114	114				106	137	132	132	135
M_1–M_3	216	216				228	253	223	260	222
Depth below M_2	127	120				127	113	113	120	133

Family EQUIDAE

MESOHIPPUS cf. M. HYPOSTYLUS Osborn

The specimens of *Mesohippus* include numerous upper and lower jaw fragments, one of them a well preserved maxilla with P^2-M^3. The characters of the teeth are distinct from the smaller, more primitive species characteristic of the fauna from Pipestone Springs, Montana, and the Cypress Hills formation (Russell, 1940) of Saskatchewan, Canada. They are in the same size range as *Mesohippus bairdii* but appear to differ from that species in the way described by Osborn for *M. hypostylus*. The hypocone is less well developed, the crests less elevated, and the individual teeth narrower. They differ from *Mesohippus proteulophus* by the smaller size and the presence of a rudimentary hypocone.

CORRELATION OF THE NEBRASKA FAUNA

Correlation of the fauna from Nebraska with that of the Chadron formation of the Big Badlands is difficult because of the lack of fossils from the lower Chadron of that area. The fauna from Pipestone Springs is usually considered a lower Chadron equivalent. The differences between that fauna and the fauna from Nebraska are marked. Aside from the fact that brontotheres are not a prominent part of the Pipestone Springs fauna, the species of *Mesohippus* are different in the two faunas. The rodents *Cylindrodon* and *Titanotheriomys* appear to be represented by different species. Some of the genera, such as *Poebotherium*, are more characteristic of middle Oliogocene than the Chadron. The differences become more marked when the ant hill specimens are included. The Pipestone Springs fauna is notable for being a fauna of small animals, jaws of rodents, insectivores, marsupials, small carnivores, and small artiodactyls being very abundant. These are the same types of specimens found in the ant hill collections. The faunal list from these even in its present unfinished state includes Orella genera which have never been reported from Pipestone Springs. Collections have been made from these deposits over a long period of years. The absence of these genera, therefore, is not due to accidents of collecting. It may be, of course, that the ant hill specimens were derived from a wider vertical range than that represented by the Chadron locality described in this paper.

The Cypress Hills fauna of Saskatchewan, Canada, is also considered in whole or in part an early Chadron equivalent. Russell (1934) commenting on Lambe's opinion that beds of middle Oligocene age might be present because of the Brule species represented, points out that the titanotheres extend to the top of the formation. He concludes, from a study of the titanothere remains and the "microfauna" which occurs in pockets in the same stratigraphic zones as the titanotheres, that the age is earliest Oligocene, perhaps equivalent to the lower barren parts of the Chadron of the Big Badlands of South Dakota.

The correspondence of species and genera in the fauna from Nebraska and that of the Cypress Hills of Canada is close. *Cylindrodon*, *Titanotheriomys*, *Leptomerys esulcatus*, *Ischyromys pliacus* occur in both. The titanotheres and horses from Cypress Hills, however, seem of a different and apparently more primitive species.

The fauna from Nebraska is also very similar, as far as comparison between a very large and a very small fauna can be made, with that of the Horsetail Creek beds (Matthew, 1901) of Logan and Weld counties, Colorado. In discussing the age of this fauna, Galbreath (1953) notes the presence of *Trigonias osborni* and *Archaeotherium crassum* which Clark (1937) thought might be restricted to middle Chadron age, and also the presence of Orella species. He concludes that the Horsetail Creek beds are not older than middle Chadron in age and might be an upper Chadron phase. *Cylindrodon* does not occur in the Horsetail Creek beds, although other rodents, *Titanotheriomys*, *Ischyromys*, *Pelycomys*, *Adjidaumo* and *Paradjidaumo* are represented. In view of the fact that *Cylindrodon* does occur in deposits generally considered lower Chadron (i.e., those at Pipestone Springs, Cypress Hills etc.) this may be significant.

All things considered the Chadron deposits near Orella, Nebraska, from which the specimens described in this paper were collected seem more nearly equivalent in age and facies with the Oligocene of the Beaver Divide above the channel fill, and the Cameron Springs beds of the Wind River

Basin, Wyoming. *Cylindrodon* is represented at all three localities, the species of *Titanotheriomys* seem to be very similar, *Mesohippus* is represented by a species, probably *M. hypostylus*, which is different from *M. bairdi* but not as primitive as the horses from Pipestone Springs or Cypress Hills, titanothere remains are abundant and of typical Chadron genera.

The writers feel, however, that before an exact stratigraphic assignment of the various scattered localities of fossils of Chadron age can be made, more attention should be paid to the possibility of regional variation. The presence of seemingly more primitive species of horses and titanotheres in one locality may not necessarily mean that the deposits in that locality are older but merely that the environment there was more favorable for these particular types. Similarly the presence of *Cylindrodon* may be due to conditions favorable for that type of rodent. We have as yet too little knowledge of the geographical distribution of many of even the commoner genera and the specific or subspecific variations which may be present in contemporaneous populations.

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JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 141–145, 4 TEXT-FIG., JANUARY 1956

NOTES ON *MODOCIA* AND MIDDLE CAMBRIAN TRILOBITES FROM WYOMING

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ABSTRACT—A semi-quantitative comparison of *Modocia oweni* (Meek & Hayden), 1862, *M. centralis* (Whitfield), 1877, and *M. weedi* (Walcott), 1899, leads to the conclusion that the last species should be suppressed as a synonym of *M. centralis*. The wider glabella and narrower fixed cheeks of the holotype of *M. oweni* are demonstrated graphically and statistically. *Crepicephalus? wyomingensis* Miller, 1936, is reassigned to *Alokistocarella*. The head of *Marjumia? tetonensis* Miller, 1936, is made the type of a new genus, *Ithyektyphus;* the pygidium assigned by Miller to this species is named *Olenoides incertus*.

MODOCIA CENTRALIS (Whitfield), 1877

Crepicephalus (*Loganellus*) *centralis* WHITFIELD, 1877, Prelim. Rept. Paleontology Black Hills, U. S. Geol. Geogr. Survey Rocky Mt. Region, p. 10, Not seen; *fide* Walcott, 1924, and Lochman & Duncan, 1944.

Crepicephalus centralis WHITFIELD, 1880, Rept. Geology & Resources Black Hills Dakota, U. S. Geol. Geogr. Survey Rocky Mt. Region, p. 341–343, pl. 2, fig. 21–24.

Solenopleura? weedi WALCOTT, 1899, U. S. Geol. Survey Mon. 32, pt. 2, p. 464–465, pl. 65, fig. 9 only.

Modocia oweni (Meek & Hayden). WALCOTT, 1925 (part), Smithsonian Misc. Coll., vol. 75, no. 3, p. 106, pl. 16, fig. 1, 2 only. Fig. 3 = *M. oweni*.

Modocia oweni (Meek & Hayden). RESSER, 1935 (part), Smithsonian Misc. Coll., vol. 93, no. 5, p. 41. References to Walcott's 1925 figures only; remainder = *M. oweni*.

Modocia centralis (Whitfield). RESSER, 1935 (part), Smithsonian Misc. Coll., vol. 93, no. 5, p. 41–42, References to Whitfield, 1877 and 1880, and to the holotype only; remainder = *M. oweni*.

Semnocephalus weedi (Walcott). RESSER, 1942, Smithsonian Misc. Coll., vol. 101, no. 15, p. 51.

Modocia centralis (Whitfield). LOCHMAN & DUNCAN, 1944, Geol. Soc. Am. Spec. Paper 54, p. 127–128, pl. 11, fig. 40–43.

Modocia weedi (Walcott). LOCHMAN & DUNCAN, 1944, *op. cit.*, p. 128–129, pl. 11, fig. 36–39.

Modocia oweni (Meek & Hayden). SHIMER & SHROCK, 1944, (part), Index Fossils of North America, pl. 265, fig. 40, 41 only. Text and figure 39 = *M. oweni*.

Modocia weedi (Walcott). PALMER, 1955, Jour. Paleont., vol. 28, p. 763.

[Probably] *Modocia* cf. *M. centralis* PALMER, 1955, *loc. cit.*, pl. 87, fig. 8.

[?] *Modocia* cf. *M. oweni* PALMER, 1955, *op. cit.*, p. 763–764, pl. 87, fig. 3, 4, 6.

It is here proposed that the trilobite names *Modocia centralis* (Whitfield), 1877, and *M. weedi* (Walcott), 1899, are synonyms.

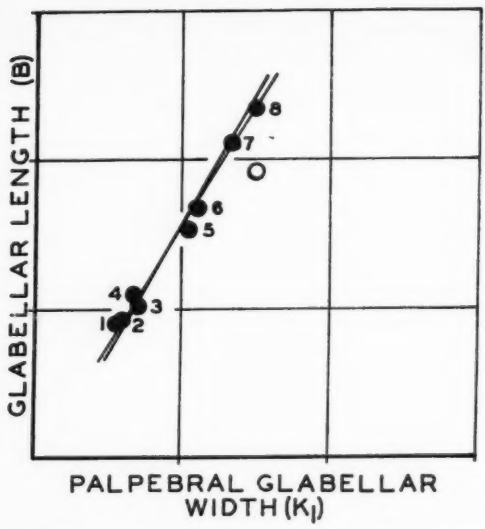
Nomenclatural history.—The history of these two names prior to 1924, when Walcott erected *Modocia*, with *Arionellus* (*Crepicephalus*) *oweni* as type, may be followed in the synonymy given above and is not reviewed, for it is not germane to the discussion that follows.

1925: Walcott described *Modocia* more fully than had been done in his original citation, and he gave a synonymy for *M. oweni* in which he suppressed *M. centralis* in favor of *M. oweni*. In his illustrations he figured USNM 1180, the type cranidium of *M. oweni* (fig. 3), and USNM 24581 (fig. 1, 2). No mention was made of *M. weedi*.

1935: Resser listed four species referable to *Modocia*, including *M. oweni* and *M. centralis*, which he resurrected as a valid species. In doing so, however, he made an error in that he cited Walcott's figures 1 and 2 as *M. oweni*, although he simultaneously cited the specimen shown in these figures (USNM 24581) as the holotype of *M. centralis*. Conversely, the true type of *M. oweni* was cited as *M. centralis*. He gave no discussion of either species, nor did he cite any means by which the species could be distinguished.

1942: Resser erected a new genus, *Semnocephalus*, for *Solenopleura? weedi*, and at the same time he limited Walcott's species to the larger of the two heads originally figured. The smaller head was called *S. minor;* no evaluation of the validity of this species can be made at this time. Resser gave no comparisons of *Semnocephalus* with other genera.

1944: Lochman & Duncan recognized both *M. weedi* and *M. centralis* in the



TEXT-FIG. *1*.—Graph of the palpebral width of the glabella and the length of the glabella for specimens of *Modocia* discussed in this paper. Open dot: holotype of *M. oweni*. Solid dots all referred to *M. centralis* in this paper. *1*, Montana Univ. MSUM T1557. *2*, Lochman coll CL 131a. *3*, MSUM T1527. *4*, Univ. Texas UT-32124. *5*, MSUM T1556. *6*, UT-32175. *7*, MSUM T1558. *8*, USNM 24581, holotype of *M. centralis*. Original identifications: *M. centralis* [1, 2, 6 (cf.), 8]; *M. weedi* (3, 5, 7); *M.* cf. *M. oweni* (4). Squares in graph 5 mm. on a side.

Cedaria zone of central Montana and compared *M. weedi* with *M. centralis* and with *M. oweni*. No direct mention was made of *Semnocephalus*, but the inclusion of the genotype in *Modocia* implicitly suppressed the genus. In their citation of *M. centralis* these authors corrected the error made by Resser and cited the proper illustrations in Walcott, 1925, but they cited Resser, 1935, without comment.

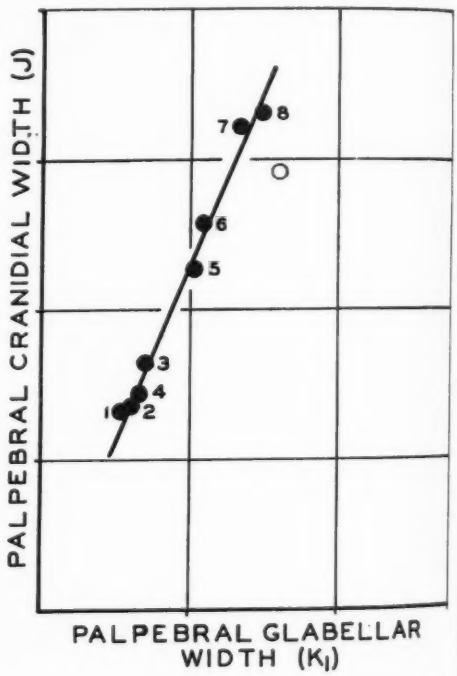
Lochman & Duncan noted the close similarity of the species in question and differentiated them as follows:

> *Modocia weedi* (Walcott) differs from *M. oweni* (Meek and Hayden) in possessing a proportionately wider, more strongly convex frontal border, and a proportionately longer and narrower glabella.
>
> *M. weedi* (Walcott) is very close to *M. centralis* (Whitfield), the only apparent differences being the somewhat more elongate, narrower glabella and slightly narrower fixed cheeks of *M. weedi* (Walcott). The proportions and shapes of the frontal limb and frontal border are the same in the two species.

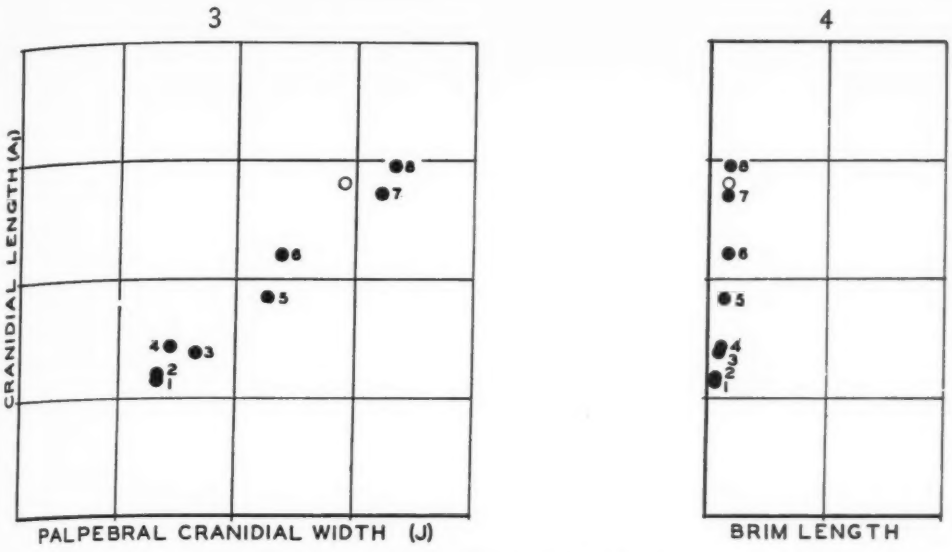
1944: Shimer & Shrock figured as *Modocia oweni* both of the specimens figured by Walcott in 1925, thus, implicitly suppressing *M. centralis*.

1955: Palmer considered *M. oweni* and *M. centralis* both to be valid and cited distinguishing characteristics of *M. oweni* and *M. centralis*. Unfortunately, the accompanying synonymies are contradictory, for the synonymy of *M. oweni* includes all of Walcott's 1925 figures, which, as we have seen, include the holotypes of both *M. oweni* and *M. centralis*. Thus, the two holotypes are regarded as belonging to *M. oweni* although both species are listed elsewhere on the page as valid.

In summary, the complicated nomenclatural history of these species leaves us with a rather confused picture and with explicit distinctions listed only between *M. weedi* and the other two species. *M. weedi* is stated to have a more elongate and narrower glabella than either *M. oweni* or *M. centralis* and to have a wider and more convex border than *M. oweni*. The statement of difference between *M. oweni* and *M. cen-*



TEXT-FIG. *2*—Symbols as in Text-fig. 1.



TEXT-FIGS. *3, 4*—Symbols as in Text-fig. 1.

tralis by Palmer is somewhat vitiated by the confusion over the position of the two holotypes.

A graphic analysis.—In order to determine what differences, if any, actually exist in the figured specimens of these species Text-fig. 1–4 were prepared, based on measurements from the photographs. Errors due to differences in orientation and to different focal lengths in the cameras used undoubtedly affect the figures used in this analysis somewhat, but they do not seem to be nearly sufficient to distort the graphs fundamentally.

Text-fig. 1 compares the width of the glabella opposite the eyes with the length of the glabella, including the occipital ring. This proportion was emphasized by Lochman and Duncan, who distinguished *M. weedi* from both *M. oweni* and *M centralis* by the elongate glabella. The figure shows that there is no separation in this regard among any of the specimens except the holotype of *M. oweni* which is significantly different. The regression formulae and standard errors of estimate for all specimens except USNM 1180 are:

$$\hat{B}=1.586K_1-0.2 \text{ mm. } (s=0.40 \text{ mm.})$$
$$\hat{K}_1=0.603B+0.3 \text{ mm. } (s=0.24 \text{ mm.})$$

where B is the length of the glabella and K_1 is the width of the glabella opposite the midpoints of the eyes. Substitution of the measurements of the holotype of *M. oweni* in these formulae and checking by the use of *t* shows that the holotype differs significantly; in the first formula $P<0.05>0.02$, and in the second, $P<0.01$. Thus, *M. oweni*, as represented by USNM 1180 has a wider glabella, for its size, than do the other specimens tested, which have the same glabellar shape except for ontogenetic changes, regardless of the species with which they have been identified. The elongate glabella that was believed to distinguish *M. weedi* and *M. centralis* does not exist.

Text-fig. 2 compares the width of the cranidium across the centers of the palpebral lobes with the width of the glabella on the same line. This is a measure of the width of the fixed cheeks, which was the only other cited difference between *M. weedi* and *M. centralis*. By inspection of the graph it may be seen that all specimens except the holotype of *M. oweni* again fall into an indivisible array. The formulae are:

$$J=2.345K_1-0.3 \text{ mm. } (s=0.5 \text{ mm.})$$
$$K_1=0.418J+0.2 \text{ mm. } (s=0.2 \text{ mm.})$$

Substitution of the dimensions of *M. oweni* (USNM 1180) and calculation of *t* reveals again that $P<0.01$, indicating that the

difference between that specimen and the others is highly significant. Thus, *M. oweni* as represented by its type specimen has narrower fixed cheeks than the other specimens figured. Conversely, this graph leads to the conclusion that there are no significant differences in the width of the fixed cheeks among the other figured specimens that cannot be accounted for as ontogenetic variation.

Text-fig. 3 shows the relation of the axial cranidial length to the cranidial width across the eyes. Text-fig. 4 plots the median length of the border against the axial length of the crandium; neither of these arrays seems to show any separation of the specimens involved, even USNM 1180, so no regression formulae were calculated. The interpretation of these graphs is that the proportions considered are generically constant.

Interpretation of the analysis.—It has been shown that, on the basis of the specimens thus far illustrated, there is no valid ground for separating *Modocia weedi* (Walcott), 1899, from *M. centralis* (Whitfield), 1877; therefore, *M. weedi* is here suppressed as a junior subjective synonym. Conversely, *M. oweni* is regarded as distinct from *M. centralis* by reason of its narrower fixed cheeks and wider glabella at comparable ontogenetic stages. No comment is made upon the specimens figured by Palmer beyond the statement that they do not differ from each other significantly in the four proportions considered here, nor does either differ significantly from *M. centralis* in these same four proportions. The remaining specimens discussed above are all referred to *M. centralis* except the holotype of *M. oweni*, USNM 1180.

Distribution.—*Cedaria* zone of the Deadwood formation of the Black Hills, of the Pilgrim formation of central Montana, and of the DuNoir limestone of Crowfoot Ridge, Yellowstone National Park, Wyoming.

ALOKISTOCARELLA WYOMINGENSIS (Miller), 1936

Crepicephalus? wyomingensis MILLER, 1936, Jour. Paleont., vol. 10, p. 29, pl. 8, figs. 9–12.
Aphelaspis wyomingensis (Miller). RESSER, 1937, Smithsonian Misc. Coll., vol. 95, no. 22, p. 2.
"*Aphelaspis*" *wyomingensis* (Miller). PALMER, 1955, Jour. Paleont., vol. 28, p. 744.

As Palmer has noted, this species is of Middle Cambrian age and does not properly belong in *Aphelaspis*. The structure of the cranidium seems to fit *Alokistocarella*, although in the absence of pygidia, assignment of these common Middle Cambrian cranidia is always tentative.

Distribution.—Only known from the type locality about 120 feet above the base of the Park shale, Crow Creek Canyon, sec. 5, T. 6 N., R. 4 W., Fremont County (Loc. 64/5A3), where it is associated with *Brachyaspidion rhynchina* (Miller), 1936, *Ehmania weedi* Resser, 1935, and *Ithyektyphus? tipperaryensis* (Miller), 1936 (see below).

Genus ITHYEKTYPHUS, n. gen.

The species described as *Marjumia? tetonensis* Miller, 1936, does not seem to belong in any described genus, and it is here made the basis of a new genus.

Description.—Genus known from the cranidium alone. Average length about 15 mm. Glabella tapered to a rather sharp point; glabellar furrows poorly impressed. Occipital furrow straight, narrow and well impressed; occipital ring uniformly wide, without spine or tubercle. Dorsal furrows deep and sharp all around. Brim very narrow in front of the glabella, slightly downsloping. Marginal furrow sharp and broadly V-shaped. Border tumid, strongly arched transversely and angular in sagittal profile, with a crest about two-thirds of the way toward the rear; border 2–2½ times as wide as the brim in the median plane. Ocular ridges faint, backswept from the first pair of glabellar furrows. Palpebral lobes, lying just posterior to the mid-length of the glabella, excluding the occipital ring, are small, gently arcuate and set off by a shallow palpebral furrow. Fixed cheeks almost semicircular in transverse profile, slightly under half the width of the glabella opposite the mid-points of the eyes; cheeks broadly convex in longitudinal profile. Posterior limbs triangular, deeply furrowed and pointed at the outer ends, about as wide as the occipital ring. Surface finely and closely granulate.

Diagnosis.—The distinctive combination of features seems to be the tumid border, very short brim and the pointed glabella, set off by deep dorsal furrows.

Remarks.—*Ithyektyphus* resembles several other late Middle and early Late Cambrian genera with a thickened border. It is much like some species of *Cedarina* Lochman, 1940, in general configuration, rounded glabella and deep dorsal furrows (see especially Lochman & Duncan, 1944, pl. 17, fig. 10), but it has normally tapered, opisthoparian posterior limbs. *Trachycheilus* Resser, 1945, is even closer in appearance, but it has a median posterior inbend of the border that *Ithyektyphus* lacks; also *Trachycheilus* appears to have a narrower border (trans.). *Solenopleurella* Poulsen, 1927, has a more transverse cranidium, more abruptly truncate glabella and a wider brim than *Ithyektyphus*. The general tumidity of the whole cranidium, and especially of the border, together with the short brim serves to distinguish this genus from *Ehmania* Resser, 1935.

The species described by Miller (1936, p. 33) as *Marjumia? tipperaryensis* and which Resser (1937, p. 18) referred to *Loncholcephalus* shows many similarities with *I. tetonensis* and is here designated *I.? tipperaryensis*. Inasmuch as no actual specimens have been available for examination at this time the reference remains tentative.

Genotype.—*Marjumia? tetonensis* Miller, 1936, restricted (see below).

Ithyektyphus tetonensis (Miller), 1936

Marjumia? tetonensis Miller, 1936 (part), Jour. Paleont., vol. 10, p. 33, pl. 8, fig. 19, 20 only. Fig. 21 = *Olenoides incertus* Shaw, n. name.
Marjumia? tetonensis Miller, 1936, Jour. Geol., vol. 44, p. 129.
Ehmania tetonensis (Miller). Resser, 1937, Smithsonian Misc. Coll., vol. 95, no. 22, p. 9.

Miller described and figured this species on the basis of cranidia and a pygidium which he believed were to be associated. However, Resser recognized that they were not properly assigned and referred the cranidium to *Ehmania* and the tail to *Kootenia*. By error, Resser continued to use the name *tetonensis* for both head and tail, although Miller's name can properly be applied only to one or the other. Had he used *tetonensis* as a new name for one shield and Miller's *tetonensis* for the other his procedure would have validated the name, but he did not, so it is necessary to propose a new name, which is done. Miller's name is restricted to the cranidium.

Cotypes.—Columbia Univ. 12607.

Topotypes.—UW IT-304 from South Fork Teton Canyon, N½, sec. 22, T. 43 N., R. 117 W., Teton County (Loc. 43117/22A2).

Distribution.—Resser erroneously cited this species and the next as being from the Wolsey shale, but Miller clearly states that the types come from the Death Canyon limestone talus on South Fork Teton Creek, and that the species occurs 75 feet below the top of the Death Canyon on Cache Creek, Gros Ventre Mountains.

Olenoides incertus, new name

Marjumia? tetonensis Miller, 1936 (part), Jour. Paleont., vol. 10, p. 33, pl. 8, fig. 21 only. Fig. 19, 20 = *Ithyektyphus tetonensis* (Miller), 1936.
Kootenia tetonensis (Miller). Resser, 1937, Smithsonian Misc. Coll., vol. 95, no. 22, p. 15.

As explained above, the pygidium of *Marjumia? tetonensis* needs a new name. However, the tail seems more properly to belong in *Olenoides* than in *Kootenia*, where it was placed by Resser.

Lectotype.—Columbia Univ. No. 12610.

Distribution.—See comments under *Ithyektyphus tetonensis*.

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Manuscript received March 5, 1955

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 146–169, 12 TEXT-FIG., JANUARY 1956

THE LOWER PLIOCENE OGALLALA-WOLF CREEK VERTEBRATE FAUNA, SOUTH DAKOTA

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ABSTRACT—A series of beds east of the town of Pine Ridge, South Dakota, consisting of volcanic ash and sandstones is considered part of the Ogallala group. A new vertebrate fauna of late Clarendonian age is described and is correlated with the Big Spring Canyon fauna. A new genus and species of insectivore, *Domninoides riparensis*, and two other new species, *Pliogale manka* and *Procamelus dakotensis*, are described. Twenty-six genera are discussed.

INTRODUCTION

In March, 1946, Mr. John Faulk of Denby, South Dakota presented to the Museum of Geology, South Dakota School of Mines and Technology, a portion of a gomphothere mandible which he had seen exposed in a blowout in the sandy ash along Wolf Creek, Shannon County, South Dakota.

Funds for field parties were unavailable until 1951 when Morton Green and J. R. Macdonald made a one day reconnaissance of the area and collected a few specimens at the blowout. The author spent two weeks in the area during the summer of 1952. James D. Bump, Vernon Bump, Rodney Rankin, Charles Wismer, and Richard Wismer also spent some time collecting for the museum. During the 1953 season, four weeks were spent in collecting and making stratigraphic observations. Richard Wismer, a student of geological engineering, studied the stratigraphy.

Permission to collect on the Pine Ridge Indian Reservation was granted by the Indian Service, U. S. Department of the Interior and by the Pine Ridge Tribal Council.

Thanks are expressed to the people of Denby and Pine Ridge, South Dakota, for information and otherwise making collecting simplified and profitable, and to James D. Bump and J. R. Macdonald for criticism of the manuscript. C. W. Hibbard's comments on some of the rodents and the soricid, T. M. Oelrich's remarks on *Testudo*, and T. M. Stout's on the beavers are gratefully acknowledged. The drawings were made by Orla Peters.

In referring to catalogued specimens in the South Dakota School of Mines and Technology collection, the abbreviation SDSM is used.

DESCRIPTION OF THE AREA AND GEOLOGIC NOTES

All of the collecting sites are south of U. S. Highway 18, extending from the town of Pine Ridge east eleven miles north of the South Dakota-Nebraska state line.

The main branch of Wolf Creek originates in Sec. 23, T. 35 N., R. 43 W., Sheridan County, Nebraska. It crosses into Shannon County, South Dakota in this section and flows northwest by west through Sections 13, 14, 11, 10, and 9 where it empties into a unnamed creek on the north side of U. S. Highway 18.

The South Fork of Wolf Creek originates in Sec. 21, T. 35 N., R. 43 W. in Sheridan County, Nebraska. It crosses into South Dakota in the southeast corner of Section 20, flowing northwest through Sections 17 and 18, emptying into the main branch just on the western boundary of Section 18.

The Nebraska Fork of Wolf Creek originates in Nebraska in Sec. 24, T. 35 N., R. 44 W., Sheridan County, Nebraska. It crosses into South Dakota in Section 24, and flows northwest through Sections 13, 14, 15, and 10 and empties into the main branch near the center of Section 9 (all T. 35 N., R. 44 W.).

The beds consist of consolidated and unconsolidated floodplain sandstones, siltstones, some sandy stream channels and pure volcanic ash. They lie unconformably on the Arikaree Group bounded on the south by the low range of hills called Pine

Ridge. These Ogallala strata are thickest in the west and thin out toward the east. The beds are here considered part of the Ogallala Group. No attempt was made to discern formations as most of the stream channels are not connected and the various exposures themselves too small for such determination.

Many of the collecting sites are in isolated exposures, either as erosional remnants or because the surrounding territory is covered (at present, 1953) with vegetation. Long time residents state that during the drought years of the early nineteen thirties the entire area was denuded of vegetation.

Direct continuity of these beds with those of Big Spring Canyon (about 30 miles to the east) has not been established. If there is any continuity the strata are covered by sand dunes. These dunes increase in thickness from the eastern limits of the Wolf Creek exposures to the vicinity of Big Spring Canyon. The distinctive volcanic ash beds in the Wolf Creek region are not present at Big Spring Canyon although there are some volcanic ash beds east of that site.

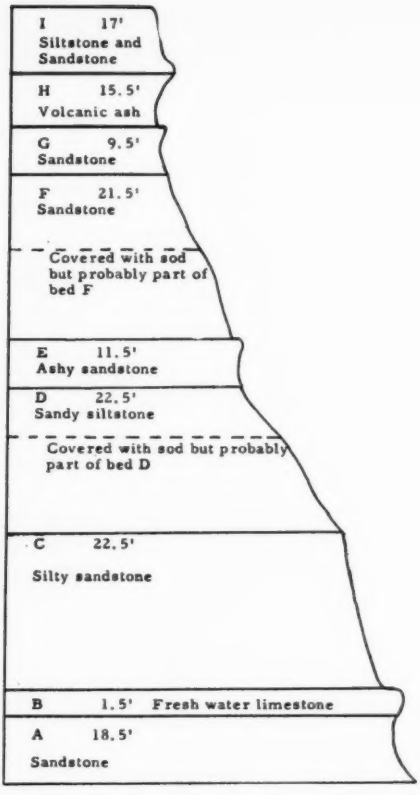
The following section from a report by Wismer (1954) is of SDSM locality V5334. Thickness given in feet. (See Text-fig. 1.)

Unit	*Description*	*Thickness*
		(*feet*)
I	White fine grained siltstone; slightly calcareous. Weathers into a rugged irregular outcrop. Grades downward into a well cemented light grey, calcareous, fine-grained sandstone. The sandstone in the lower part of this bed contains a small amount of volcanic ash.	17
H	Pure white volcanic ash forms an undercut cliff with the sandstone projecting above it. Grades upward within one foot into the sandstone.	15.5
G	Unconsolidated fine grained light brown sandstone. Larger grains subrounded and frosted. Smaller grains angular and not frosted. Sharp contact with overlying volcanic ash and underlying sand.	9.5
F	Poorly sorted fine to medium grained semi-consolidated sandstone. Greenish color when damp. Sub-rounded grains with occasional frosting. Siliceous or clay cement. Top five feet exposed with remainder covered with sod.	21.5
E	Well cemented calcareous ashy sandstone. Quartz grains constitute 70 per cent and volcanic ash 20 per cent of this outcrop.	11.5
D	Light brown to white very fine to medium grained sandstone with calcareous cement. Forms banks where well cemented, otherwise slopes. Varies vertically from silty to pebbly sandstone, the pebbles being very fine sandstone and calcareous material. Scattered small flakes of golden mica present.	22.5
C	Light brown, very fine to medium grained, poorly cemented sandstone. Cemented with a small amount of clay material. Top at same level as bottom of bed D but 300 feet from it. This is probably the lower part of bed D with the calcareous material leached out.	22.5
B	White, fresh water limestone with a few quartz grains. Black dendrites and calcareous tubes common. Forms a resistant ledge between sands.	1.5
A	Light brown unconsolidated fine to medium grained sandstone. Frosted subrounded clear quartz with a trace of dark minerals.	18

LIST OF LOCALITIES AND GENERA
(See map, Text-fig. 2)

All localities listed are of the Museum of Geology, South Dakota School of Mines and Technology, Rapid City, South Dakota.

Loc. V521. SW¼ SE¼ Sec. 16, T. 35 N., R. 43 W., Shannon County, South Dakota. Sandstone about 25 feet above the stream floor just on the east side of the north-south quarter section fence line. *Alilepus, Hypolagus, Pliosaccomys, Eucastor, Amebelodon, Merycodus, Meryceros.*



TEXT-FIG. *1*.—Diagrammatic section of SDSM locality V5334 (from Wismer, 1954).

Loc. V522. SW¼ SE¼ Sec. 16, T. 35 N., R. 43 W., Shannon County, South Dakota. Sandstone in the first gulley east of V521 on the north side of the creek. *Neohipparion.*

Loc. V523. SE¼ SW¼ Sec. 16, T. 35 N., R. 43 W., Shannon County, South Dakota. Brownish sand in the first gulley just west of V521 on the north side of the creek. *Eucastor, Merycodus.*

Loc. V524. SE¼ SE¼ Sec. 16, T. 35 N., R. 43 W., Shannon County, South Dakota. Sandstone on the north side of the creek, just above the stream floor. *Brachypsalis, Merycodus.*

Loc. V525. NE¼ SE¼ Sec. 17, T. 35 N., R. 43 W., Shannon County, South Dakota. Clean white loosely consolidated volcanic ash on the north side of the creek. *Nannippus, Neohipparion, Pliohippus.*

Loc. V526. NW¼ SE¼ Sec. 17, T. 35 N., R. 43 W., Shannon County, South Dakota. Clean white loosely consolidated volcanic ash on the north side of the creek; first exposure west of V525. *Nannippus, Pliohippus.*

Loc. V527. SW¼ SW¼ Sec. 16, T. 35 N., R. 43 W., Shannon County, South Dakota. Clean white loosely consolidated volcanic ash in a small canyon on the south side of the creek the entrance of which is almost directly opposite V525. *Neohipparion, Pliohippus, Teleoceras, Procamelus.*

Loc. V528. SE¼ SE¼ Sec. 17, T. 35 N., R. 43 W., Shannon County, South Dakota. Sandy white ash in a canyon on the south side of the creek almost opposite V526. *Procamelus.*

Loc. V529. Floor of the creek in Sections 16 and 17, T. 35 N., R. 43 W., Shannon County, South Dakota. All of the specimens from this locality are regarded as float. None of them differ in any way from those found in place. *Eucastor, Nannippus, Neohipparion, Pliohippus, Teleoceras, Pliauchenia, Merycodus.*

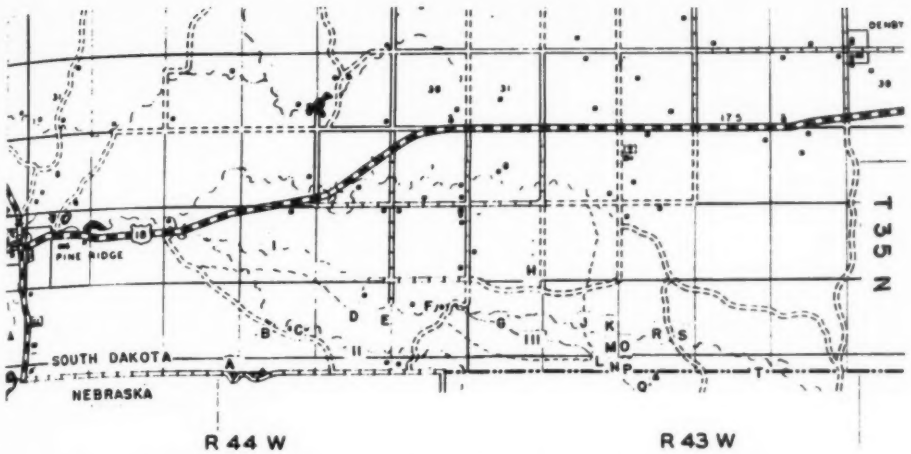
Loc. V5322. NE¼ NE¼ Sec. 21, T. 35 N., R. 43 W., Shannon County, South Dakota. A bluff forming white volcanic ash. *Felis.*

Loc. V5323. NW¼ NW¼ Sec. 21, T. 35 N., R. 43 W., Shannon County, South Dakota. Two small bluffs of white volcanic ash. *Procamelus.*

Loc. V5324. Sec. 20, T. 35 N., R. 43 W., Shannon County, South Dakota. On the north side of the South Fork of Wolf Creek. Two "U" shaped canyons closed at the north end and separated from each other by an intervening ridge. Covered with vegetation (1953). Brown sand with a few feet of sandstone at the top. *Pseudaelurus, Nannippus, Neohipparion, Pliohippus, Teleoceras, Parablastomeryx, Merycodus.*

Loc. V5325. SW¼ NE¼ Sec. 20, T. 35 N., R. 43 W., Shannon County, South Dakota. A blowout of brown sand on the south side of the South Fork of Wolf Creek opposite V5324. At the south end of the blowout almost on the South Dakota-Nebraska fence line is a cone shaped hill, Lone Ash Point. This hill is considered part of the locality. *Nannippus, Neohipparion, Pliohippus, Paracamelus.*

Loc. V5326. SE¼ NW¼ Sec. 21, T. 35 N., R. 43 W., Sheridan County, Nebraska. An ash and sandstone exposure, just over the



TEXT-FIG. 2—Portion of General Highway Map, south half Shannon County, Pine Ridge Indian Reservation, South Dakota. South Dakota State Highway Commission. 1936.
The localities mark the approximate extent of Ogallala exposures in the Wolf Creek drainage.
Key: I. Wolf Creek; II. Nebraska Fork of Wolf Creek; III. South Fork of Wolf Creek; A. V5327; B. V5334; C. V5336; D. V5333; E. V5332; F. V5331; G. V5335; H. V5329; J. V5328; K. V525 and V526; L. V5324 and V5325; M. V528; N. V5322; O. V527; P. V5323; Q. V5326; R. V521, V522, and V523; S. V524; T. V5330; V529 not marked, creek bed. Dashed lines on map represent trails existing in 1953.

South Dakota-Nebraska boundary. *Testudo, Pliogale, Nannippus, Pliohippus, Merycodus.*

Loc. V5327. NE¼ NE¼ Sec. 21, T. 35 N., R. 43 W., Shannon County, South Dakota. Three miles east of South Dakota Highway 77 along the "Border Road" which runs along the state line. Large exposure of ash and sandstone. *Nannippus, Neohipparion, Cranioceras.*

Loc. V5328. SW¼ SW¼ NE¼ Sec. 17, T. 35 N., R. 43 W., Shannon County, South Dakota. Small exposures of sand, volcanic ash, and sandy ash along trail leading to creek. The beds begin north of the creek at the descent off the table to the creek valley. *Tomarctus, Nannippus, Neohipparion, Pliohippus, Teleoceras, Peraceras, Merycodus.*

Loc. V5329. SE¼ SE¼ SE¼ Sec. 7, T. 35 N., R. 43 W., Shannon County, South Dakota. Sand capped by hard massive sandstone. *Nannippus, Neohipparion, Pliohippus.*

Loc. V5330. SE¼ SE¼ Sec. 22, T. 35 N., R. 43 N., Shannon County, South Dakota. Small exposures along the South Dakota-Nebraska fence line; most of the exposures in the gulley on the Nebraska side. *Testudo, Nannippus, Neohipparion, Teleoceras, Paracamelus.*

Loc. V5331. N½ Sec. 13, T. 35 N., R. 44 W., Shannon County, South Dakota. Small exposures of sandstone on the north side of the creek on the north-south quarter section line. *Pliocyon.*

Loc. V5332. NE¼ NE¼ SE¼ Sec. 14, T. 35 N., R. 44 W., Shannon County, South Dakota. Small exposures just south of the main branch of Wolf Creek. *Nannippus, Neohipparion, Pliohippus.*

Loc. V5333. NE¼ SE¼ Sec. 14, T. 35 N., R. 44 W., Shannon County, South Dakota. Series of small exposures of ash and sandstones running along the Nebraska Fork of Wolf Creek. *Nannippus, Neohipparion, Pliohippus, Teleoceras, Peraceras.*

Loc. V5334. NE¼ NE¼ SW¼ Sec. 15, T. 35 N., R. 44 W., Shannon County, South Dakota. Sandstones and ash. The largest known section in the area, only the top of which can be seen from U. S. Highway 18. These beds swing around to the south and connect with those of V5327. *Domninoides, Nannippus, Longirostromeryx.*

Loc. V5335. NE¼ NE¼ SW¼ Sec. 18, T. 35 N., R. 43 W., Shannon County, South

TABLE 1.—GEOLOGIC RANGE OF GENERA

Genus	Middle Miocene or earlier	Upper Miocene	Lower Pliocene	Middle Pliocene	Later
Domninoides					
Alilepus					
Hypolagus					
Mylagaulus					
Pliosaccomys					
Eucastor					
Pliocyon					
Tomarctus					
Brachypsalis					
Pliogale					
Pseudaelurus					
Felis					
Amebelodon					
Nannippus					
Neohipparion					
Pliohippus					
Teleoceras		?			
Peraceras					
Procamelus					
Pliauchenia					
Paracamelus					
Parablastomeryx					
Longirostromeryx					
Cranioceras					
Merycodus					
Meryceros					

Dakota. Exposures of brown sand with overlying ash. *Mylagaulus, Nannippus, Pliohippus, Teleoceras, Merycodus.*

Loc. V5336. NE¼ SE¼ Sec. 15, T. 35 N., R. 43 W., Shannon County, South Dakota. Small sandy exposures along the Nebraska Fork of Wolf Creek just east of V5334. *Merycodus.*

AGE OF THE FAUNA AND RANGES OF GENERA

The following genera are not known below the lower Pliocene and are indicative of a Clarendonian age for this fauna: *Alilepus, Pliosaccomys, Eucastor, Pliogale, Felis, Nannippus, Neohipparion, Pliohippus, Pliauchenia,* and *Paracamelus.* Genera not known to occur above the lower Pliocene are: *Domninoides, Mylagaulus, Pliocyon, Tomarctus, Pliogale, Teleoceras, Peraceras, Procamelus, Parablastomeryx, Longirostromeryx, Cranioceras, Merycodus,* and *Meryceros.* Limited to the lower Pliocene are *Pliohippus pernix* and *P. martini.* (See Table 1.)

The species of horses offer the best evidence for determining the temporal position of the fauna within the lower Pliocene. *Nannippus gratus, Neohipparion occidentale, Pliohippus pernix* and *Pliohippus* (*A.*) *martini* are restricted to the uppermost lower Pliocene. Therefore, the Ogallala-Wolf Creek local fauna is late Clarendonian in age, most closely correlative with the Big Spring Canyon local fauna, and the Ogallala-Mission local fauna (undescribed) of South Dakota.

DESCRIPTIONS OF MATERIAL

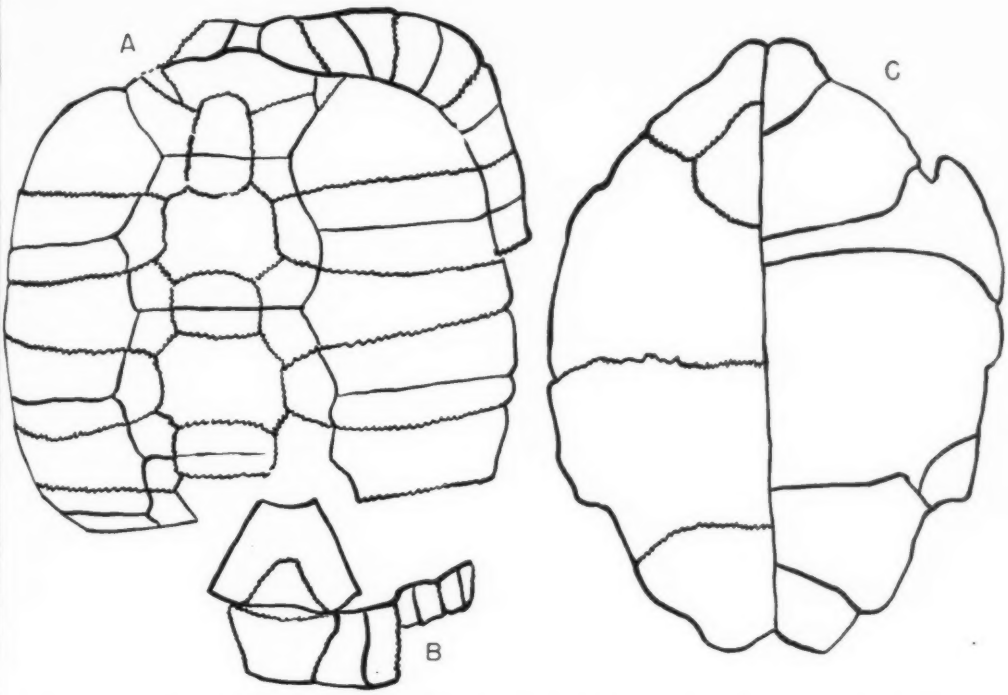
Pisces, fam. indet.

Loc. V521: SDSM 5262, a portion of a serrated spine (supraoccipital?). SDSM 53161, a portion of a smooth spine (fin?).

Loc. V5336: SDSM 5390, a spine (fin?) and a portion of an "opercular" (not associated).

Class REPTILIA
Order TESTUDINATA
Family TESTUDINIDAE
TESTUDO NIOBRARENSIS Leidy
(Text-fig. 3)

Loc. V5326: SDSM 5371, a nearly com-



TEXT-FIG. 3—*Testudo niobrarensis*. SDSM 5371, ×⅓. A. Major portion of carapace. B. Pygal region of carapace. C. Plastron. Drawings by author.

plete carapace and a complete plastron.

Loc. V5330: SDSM 5370, complete plastron, fragments of carapace, and miscellaneous limb elements.

Emended diagnosis.—Epiplastron less broad anteriorly than in *T. rexroadensis* Oelrich, broader than in *T. orthopygia* (Cope); plastron narrow as in *T. rexroadensis;* pectoral scute not in contact with entoplastron; xiphiplastron pointed posteriorly; nuchal scute broader at posterior end rather than at anterior end as in *T. orthopygia.*

Comparison.—Carapace. Thin as in *T. orthopygia,* thickening with age relative to increased size. The posterior portion of the neural plate and the anterior portion of the first neural are elevated into a wide boss which narrows to a point anteriorly. This is similar to *T. orthopgyia* (Hay, 1908, pl. 17, fig. 7).

Plastron. The epiplastra seem to develop an antero-medial depression with increase in size. The pectoral scute of the larger specimen displays the antero-posterior thinning in the center as it does in *T. rexroadensis* (Oelrich, 1952), but this is not so in the smaller specimen. This condition is also present in *Gopherus pansa* (Hay, 1908, fig. 551).

This species is closely related to *T. orthopygia* and may be ancestral to it and possibly to *T. rexroadensis* as well.

Characters overlapping *Gopherus* are: no nuchal indentation; pectoral scute separated from entoplastron and median sulcus is 10 percent of the median abdominal sulcus. Characters of *Testudo:* nuchal scute longer than wide; carapace high and globular (despite crushing which has made the carapace too wide for the plastron in SDSM 5371); fourth vertebral scute is as long as wide; the neural plates are fully differentiated.

Discussion.—This species was omitted by Williams (1950). Prior to the discovery of the specimens from Wolf Creek, the type could have been considered indeterminate and the name, *Testudo niobrarensis,* a nomen vanum. With the use of the material now on hand, I think it better to

TABLE 2.—MEASUREMENTS IN MILLIMETERS OF *Testudo niobrarensis* AND *T. rexroadensis*

Plastron	*T. niobrarensis*		*T. rexroadensis**
	SDSM 5370	SDSM 5371	
Length along midline	405	210	710
Extension of apices of xiphiplastra beyond posterior midline	12 mm. or .029% of midline	9 mm. or .042% of midline	24 mm. or .034% of midline
Width at hypoplastral peripheral suture	150 or 39% of midline	79 or 37% of midline	530 or 74% of midline
Length of anterior lobe	225 or 56% of midline	115 or 55% of midline	430 or 60% of midline
Entoplastron: width×length	107×87	47×45	195×180
Percentage of length to width	81%	95%	92%
Pectoral scute length	25.5	8.5	42
% of total midline length	6%	4%	6%
% of abdominal midline length	11%	10%	20%

* From Oelrich 1952.

establish firmly *T. niobrarensis* rather than leave it in the limbo of nomina vana and have to add a new name to the probably already overcrowded list of *Testudo* species. The character of the epiplastron referred to in the diagnosis can be seen in Leidy's type.

Leidy (1873) stated that the type was collected by Hayden, "in the Pliocene sands of the Niobrara River." Hay (1908) considered the deposits as, "Loup Fork Miocene," but later (1930) in his "Second Bibliography" gave the age as Pleistocene. This, probably because the type of the Loup Fork was established as Pleistocene. Possibly the type is from the Minnechaduza fauna. There seems to be no question, now, of properly assigning *T. niobrarensis* to the late lower Pliocene. It is the only known species of *Testudo* of Clarendonian age unless *T. louisekressmani* from Florida is not Blancan or Hemphillian. (See Table 2 for measurements.)

TESTUDINIDAE gen. indet.

Loc. V5324: SDSM 53160, an ungual phalanx belonging to a large animal. Greatest length, 46.3 mm.

Class MAMMALIA
Order INSECTIVORA
Family SORICIDAE
Genus DOMNINOIDES,* n. gen.

Type species.—Domninoides riparensis, n. sp.

Generic diagnosis.—Hypoconid connected to metaconid by ridge; talonid valleys of M_{2-3} open lingually; talonid of M_3 not reduced.

Domninoides riparensis,† n. sp.
Text-fig. 4

Holotype.—SDSM 53107; left mandible with broken I_1, roots of P_{1-2}, P_3—M_3 complete.

Diagnosis.—Anterior cingula of M_{2-3} strongly developed.‡

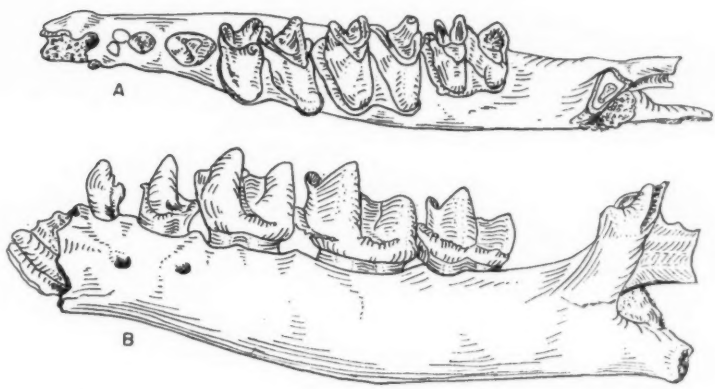
Type locality.—V5334.

Description.—I_1: slightly procumbent, similar to *Domnina*. P_1: slightly procum-

*Domnina+like

† In allusion to Wolf Creek.

‡ This diagnosis is made in order to differentiate at this time from a specimen of the same genus from the lower Rosebud (Arikareean) of South Dakota.



TEXT-FIG. 4—*Domninoides riparensis*, n. sp., type specimen, SDSM 53107, ×5. A. Occlusal view of jaw. B. External view of mandible.

bent, single rooted, somewhat caniniform, larger than P_{2-3}* P_2: double rooted, roots set transversely to length of jaw. P_3: double rooted, roots set transversely to length of jaw, cusp slightly recurved posteriorly, small posterior cingulum and heel. Small diastema between P_3–P_4. P_4: double rooted, roots anterior and posterior in position; small anterior cingulum; labial cingulum well developed, connected to broad well developed posterior cingulum (heel); no internal cingulum; cusp slightly recurved. M_1: paraconid low, connected to protoconid by ridge; protoconid highest cusp of trigonid, appressed to metaconid; metaconid higher than paraconid; talonid longer transversely than trigonid; small metastylid directly behind and attached to metaconid; hypoconid connected to metastylid by diagonal ridge and to entoconid by transverse ridge; short narrow ridge between metastylid and entoconid closes talonid valley. Low labial cingulum between protoconid and hypoconid; low posterior cingulum expanded into triangle behind entoconid; no anterior cingulum except for small antero-lingual parastylid. M_2: trigonid as in M_1 but longer transversely; talonid only slightly longer transversely than trigonid; reduced metastylid; hypoconid connected to metaconid by diagonal ridge and to entoconid by transverse ridge; talonid valley open between metaconid and entoconid; broad anterior cingulum; labial and posterior cingula as in M_1. M_3: smaller than M_2; trigonid as in M_2; no metastylid; talonid as in M_2 but shorter transversely than trigonid; cingula as in M_2 except no posterior cingulum. Mental foramina beneath labial root of P_3 and posterior root of P_4.

Discussion.—Domninoides differs from *Domnina* in that the talonid is connected to the metaconid in the former and to the middle of the posterior end of the trigonid in the latter. Although M_3 is smaller it does not have a reduced talonid as in *Domnina*.

The trend in *Domnina* seems to be a reduction of the talonid in M_3. If *Domninoides* is descendant from *Domnina* there is either a reversal of this trend or else there are species of *Domnina* not yet known in which the talonid is not reduced. This latter suggestion need not be of important consideration if we assume, in the first place, that *Domnina* is ancestral to *Domninoides*. In the Museum of Geology is a specimen, SDSM 53381, from the Lower Rosebud referable to *Domninoides* but distinct from *D. riparensis*. The cingula of M_{1-3} in *Domnina gradata* Cope are well developed. In the Rosebud species, these cingula in M_{2-3} (M_1 missing) are present but reduced in antero-posterior breadth. In *Domninoides riparensis* these cingula are again strongly developed. There is no trace of the anterior cingulum in M_1. It seems probable that the

* These teeth, I_1–P_3, were whole and intact when the specimen was collected but have since been broken off and lost. The description, therefore, is wholly dependent on the writer's memory of preliminary examination.

TEXT-FIG. 5.—A. ? *Alilepus* sp. SDSM 5271, ×5; left P_3. B. *Pliosaccomys* cf. *P. dubius*. SDSM 5264, ×5; right P_4. C. *Pliosaccomys* cf. *P. dubius*. SDSM 5264, ×5; left P_4.

trend has been for total loss of the anterior cingulum in M_1 with a reversal of the trend toward better developed cingula in M_{2-3}. It would be interesting to know the condition of the cingulum in M_1 of the Rosebud species.

The greatest change between the Oligocene genus and *Domninoides* is the shifting of the hypoconid crest from the center of the posterior of the trigonid to a connection with the metaconid.

D. compressa Galbreath resembles *Domninoides* in the open talonid valleys. These valleys are closed by a ridge in *D. gradata* Cope and *D. thompsoni* Simpson. It differs in loss of the anterior cingulum in M_2 and having a small cingulum in M_1.

Exposure of the teeth to ultraviolet light in both the Rosebud and Wolf Creek specimens reveals no fluorescence whatsoever. While successful demonstration of differentiation of fluorescence in fossils may be valuable in corroborating soricid affinities (Patterson & McGrew, 1937) caution should be made that negative results are not to be construed as denying such affinity. Different conditions and type of replacement may be responsible for lack of fluorescent differentiation.

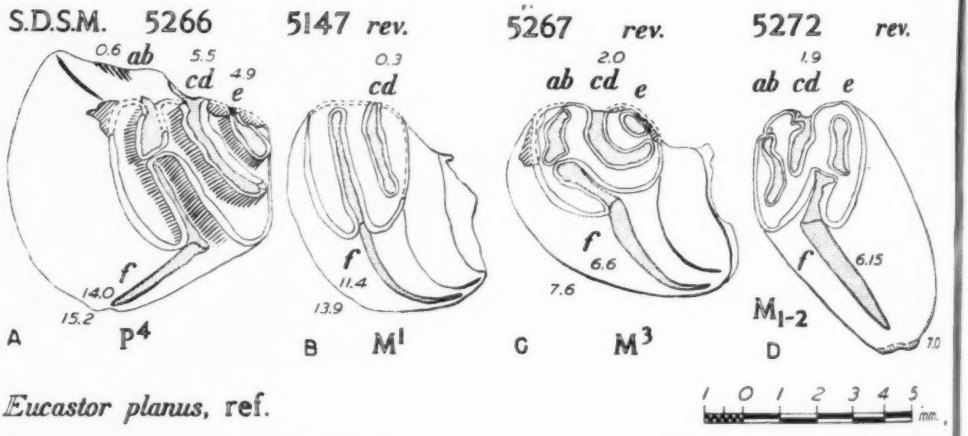
Measurements in millimeters

Domninoides riparensis, SDSM 53107

Length P_1–M_3	11.0
P_4, antero-posterior diameter	1.2
P_4, transverse diameter	.7
Length M_1–M_3	7.4
M_1, antero-posterior diameter	2.2
M_1, transverse diameter	1.9
M_2, antero-posterior diameter	2.3
M_2, transverse diameter	2.0
M_3, antero-posterior diameter	1.5
Depth of jaw under M_1	2.0

Order LAGOMORPHA
Family LEPORIDAE
?ALILEPUS sp. indet.
Text-fig. 5A

Loc. V521: SDSM 5271, a left P_3, evidently belongs to this genus. It differs from *Alilepus* (?) *vagus* Gazin from the Hagerman beds, Idaho (Blancan) in the following details. The anterior lophid is not triangular in shape. The anterior external inflection is very shallow, more so than in *A. vagus*. It is



Eucastor planus, ref.

TEXT-FIG. 6—*Eucastor planus*. Early mature stage of wear. A, left P^4, broken slightly; B, right M^1 (reversed); C, right M^3, broken slightly (reversed); D, right M_1 or M_2 (reversed). Grooves ab, cd, e, and f are shown with depths of grooves given in millimeters. The internal crown height for the upper cheek teeth and the external crown height for the lower cheek teeth are also noted. The groove-base relations (groove depths subtracted from crown height) are generally reliable when taken together with measurements noted here and dimensions for the wear (triturating) surfaces, for specific determination. Data and drawings by T. M. Stout. All figures ×5.

continuous to the base of the tooth. The posterior external inflection opens widely but extends only one-third across the tooth while in *A. vagus* this inflection has a narrow opening and extends halfway across the tooth. The deeper inflection in the Wolf Creek specimen is the internal and is separated from the posterior external inflection by a narrow dentine bridge. The depth of the inflections across the tooth are just the opposite of the condition in *A. vagus*. If both the Hagerman and Wolf Creek specimens are referable to *Alilepus*, they are not the same species. If the specimen in question is properly assigned to *Alilepus*, the range of this genus is extended to the Lower Pliocene. If it is not *Alilepus*, I know of no other genus to which it might be referred.

HYPOLAGUS sp. indet.

Loc. V521: SDSM 5273, a right M_3, is indistinguishable from other M_3's of this genus.

LEPORIDAE gen. indet.

Loc. V521: SDSM 5275 a fragment of right lower cheek tooth with the inner half of the protolophid missing, is high crowned, the opening of the external inflection is narrow, and the posterolophid is broadly "U" shaped. This tooth is possibly referable to *Alilepus*. I have seen no lagomorph with the "U" shaped posterolophid. A lower cheek tooth SDSM 52141, is not determinable generically.

Order RODENTIA
Family MYLAGAULIDAE
MYLAGAULUS sp. indet.

Loc. V5335: SDSM 53127, a right P^4. The pattern of the fossettes is not at all like that of the *Mylagaulus* from Big Spring Canyon. In length of crown the two are nearly the same; the Wolf Creek specimen is slightly wider and higher crowned but is a little more worn. This, of course, could account for the difference in pattern. However, the dental patterns in mylagaulids vary, from one jaw to another, even in the same individual. The type of *Epigaulus minor* Hibbard & Phillis (1945, fig. 2A) demonstrates this very well. The specimen possibly belongs to *Mylagaulus monodon* Cope. Antero-posterior diameter, 10.2 mm.; transverse diameter, 7.2 mm.; height, 17.0 mm.

Family GEOMYIDAE
PLIOSACCOMYS cf. P. DUBIUS Wilson
(Text-fig. 5B, 5C)

Loc. V521: SDSM 5264, a right worn P_4, is close to *P. dubius* Wilson from the Smith's Valley fauna, Nevada. The Wolf Creek tooth is a little less worn than CIT 1804 (Wilson, 1936) but more worn than in the type. A second tooth, SDSM 5264, left P_4, is much more worn with the dentine bridge very broad. Both of the Wolf Creek are a little larger than P_4 of the type. SDSM 5269, a right M_2, is also referable here.

Family CASTORIDAE
EUCASTOR PLANUS Stirton
Text-fig. 6

Loc. V521: SDSM 5272, a right M_1 or M_2; SDSM 5267, right M^3.

Loc. V523: SDSM 5266, a left P^4.

Loc. V529: SDSM 5147, two right M^1.

The following comments on these teeth have been supplied through the courtesy of T. M. Stout.

This species is considered to constitute one link or unit in the essentially monophyletic *Eucastor* Leidy lineage, ancestral to *Dipoides* Jäger. The cheek teeth of *Eucastor* are rooted from an early period in the individual's tooth development, and the grooves toward the bases of the teeth in successive species, keeping pace with a progressive hypsodonty and increase in general

Measurements in millimeters

	P. dubius CIT 1796*	SDSM No. 5264 Right	SDSM No. 5264 Left	SDSM No. 5269
P_4, antero-posterior diameter	1.3	1.8	1.7	
P_4, transverse diameter	1.3	1.1	2.0	
M_2, antero-posterior diameter	1.1			1.2
M_2, transverse diameter	1.7			1.5

*From Wilson, 1936.

size in the lineage. The larger and higher crowned cheek teeth of *Dipoides* are essentially rootless, or approach this condition except for the still retained rooted deciduous premolars; and the grooves have migrated to or near the bases of the other cheek teeth. Unfortunately, the type of the genus, *D. problematicus*, is less advanced over the condition seen in *Eucastor* than is true for the other species of *Dipoides*.

As defined in a work shortly to be published (Stout, MS), *Eucastor planus* is considered to be limited to the lower to middle Ash Hollow formation of the Ogallala group of the Nebraska section and thus assigned to the early part of the medial Pliocene. [Late Clarendonian. M.G.]

The wear-surface (triturating) measurements in millimeters for the specimens figured are recorded here in the order, (1) antero-posterior length; (2) anterior width; and (3) posterior width. SDSM 5266 (P^4), 4.4, 4.0, 3.75; SDSM 5147 (M^1), 2.8, 3.65, 3.55; SDSM 5267 (M^3), 3.4, 2.95, 2.2; SDSM 5272 (M^1 or M^2), 3.15, 3.25, 3.4.

EUCASTOR sp. indet.

Loc. V521: SDSM 52142, a little worn M^3, smaller than M^3 of *E. planus*, is not specifically determinable.

RODENTIA indet.

Loc. V521: SDSM 5268. A number of incisors belonging to different types of rodents, judging from their shapes and sizes, indicates the presence of genera other than those cited.

Order CARNIVORA
Family CANIDAE
Genus cf. PLIOCYON

Loc. V5331: SDSM 53164, a left mandibular symphysis with incisor root, alveoli for P_{2-3}. The incisor root is sub-oval in shape; P_1 is absent; there is a small diastema between P_2 and P_3. This specimen is referred here because of the absence of P_1 and its similarity in size to *P. walkerae* Johnston and Christian.

TOMARCTUS sp. indet.

Loc. V5328: SDSM 53133; a fragment of right mandible with alveoli for P_{1-3}, broken P_4—M_1 is a little larger than *T. euthos* McGrew from the Burge fauna. The premolars in the Wolf Creek specimen are crowded together in a straight line. P_4 and M_1 are too badly broken for direct comparison.

CANIDAE gen. indet.

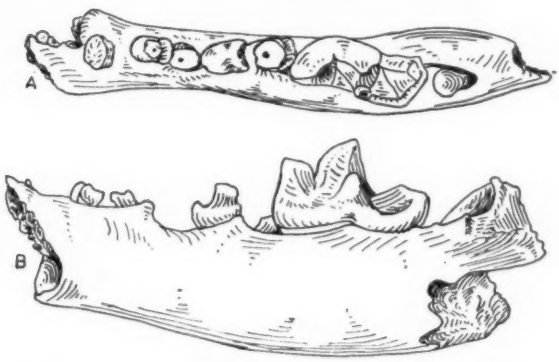
Loc. V5321: SDSM 53144, a left Mt III and a proximal phalanx possibly belong to *Tomarctus* or some other dog the size of a large *Canis latrans*.

Loc. V5324: SDSM 53135, a left calaneum, possibly referable to *Aelurodon*, is 53.4 mm. long and 21.4 mm. wide.

Family MUSTELIDAE
BRACHYPSALIS PRISTINUS (Matthew)

Loc. V524: SDSM 52108, portion of right periotic region, swollen portion of bulla lost. Ventral side of bulla and basioccipital foraminulate. Dorsal fragment of braincase provides no informaiton as with a fragment of zygoma. Portion of right maxilla with alveolus for I^3, root of C, root of P^1, broken P^2, P^3 complete, broken P^4. I^3: appears to have been a stout tooth judging from the large size of the alveolus. C: moderately compressed laterally; robust. P^1: vestigial, single rooted, directly behind canine, appressed against center of P^2. P^3: directed antero-lingually; simple, with prominent heel; broader posteriorly than anteriorly; anterior end lies forward of posterior end of canine. P^3: stout; directed antero-lingually; stout anterior and posterior accessory cusps; main cusp recurved posteriorly; anterior end narrower than posterior. P^4: broken; large tooth with well developed deuterocone. Maxilla foraminulate. Portion of left maxilla and zygoma with alveolus for P^4 (including root of paracone) and M^1. P^4: a large stout tooth; large metaconal blade indicated by large alveolus; deuterocone also large by the same indication. M^1: protocone attached to paracone by minute ridge; paracone larger than metacone; shelf expanded posterolingually. A small alveolus for M^2 is present.

M^1 closely resembles that of the specimen referred to *B. pristinus* from the Snake Creek beds, Olcott Hill (AMNH 18268) by Matthew (1924). The type of *B. pristinus* (Matthew) is a lower jaw, "from the quarry at the Cañon of the Little White River, S.



TEXT-FIG. 7—*Pliogale manka*, n. sp., type specimen, SDSM 5372, ×2. A Occlusal view of jaw. B. Medial view of mandible.

Dakota" (Matthew, 1904). Matthew (1924) states that the type is from the Valentine beds but this, I believe, is an error. The reference of 1904 is possibly to Big Spring Canyon from which the American Museum of Natural History made a collection in 1903. If Matthew's reference of the upper dentition from Olcott Hill and a separate lower dentition to the type from South Dakota is correct and the species is limited in vertical range, then *B. pristinus* could be a lower Pliocene index. We cannot be certain of Matthew's doubtful assumption even on the basis of good occlusion since the two specimens are from separate geographic localities. However this may be, it would be better to allow the nomenclature to remain as it is. Revision must await the discovery of an associated upper and lower dentition.

Henshaw (1942) referred separate upper and lower dentitions from Tonopah, Nevada (upper Miocene) to *B. pachycephalus* Cope. *B. pristinus* is more advanced in its more crowded massive teeth and the greater reduction of P^1. The crowding of P^{2-3} has forced them to sit obliquely in the maxilla. This condition is seen in *B. obluiquidens* Sinclair from the upper Snake Creek, *B. modicus* Matthew (lower Snake Creek), and *B. matutinus* Matthew (lower Snake Creek). *Aelurodon hyaenoides* seems properly referable to *Brachypsalis* as Matthew suggested.

PLIOGALE MANKA,* n. sp.
Text-fig. 7

Holotype.—SDSM 5372, right mandibular ramus with canine alveolus, alveolus for P_1, P_2–P_4 broken at or just above roots, M_1 complete, alveolus for M_2.

Type locality.—V5326.

Diagnosis.—Larger than *P. furlongi* (Merriam). M_1 hypoconid very large, filling more than half of talonid basin; entoconid ridge-like, slightly cuspidate; hypoconulid crest blended into hypoconid.

Description.—Canine circular, judging from alveolus. Premolars increase in size from P_1 to P_4; cusps broad. P_1: broken at root; single rooted, small. P_2: double rooted; small ridge down center of posterior side; small posterior cingulum. Small diastema between P_2—P_3. P_3 with anterior cingulum; posterior cingulum broken off. P_4: with anterior cingulum; ridge down center of posterior side; posterior cingulum large; postero-lingual corner flattened by appression to antero-labial paraconid blade of M_1. M_1: with thick paraconid, protoconid, and metaconid; trigonid long and wide; talonid short, slightly narrower than broadest portion of trigonid. M_2 single rooted, reduced.

Comparison.—*P. manka* is larger than *P. furlongi* (Merriam) from the Thousand Creek (Hemphillian) Nevada fauna. It differs principally in the development of the hypoconid which is larger than the metaconid. The notch separating the protoconid from the talonid is not as pronounced. There

* Sioux Indian for "skunk"; pronounced, mänkà. Name provided by Mr. Web Hill, Rapid City authority on the Sioux Indians.

is a mental foramen below the center of P_4 as in the type of the genus plus a larger foramen below the center of P_3. The antero-labial corner of M_1 is appressed against the postero-lingual corner of P_4 and extends forward of the posterior border of P_4. The position of the posterior alveolus of P_4 in *P. furlongi* indicates that the same situation is present in that species. However, this condition also exists in other mustelids and cannot be considered as generically diagnostic. The length of the talonids in both species is about the same. The trigonid in the Wolf Creek species is much longer.

Family Felidae
Pseudaelurus sp. indet.

Loc. V5324: SDSM 53152, a fragment of right mandible with roots of canine, P_3 and P_4. This specimen compares favorably with a cast of the type of *P. pedionomus* Macdonald. The shape and position of the alveoli are the same. The broken P_3 is 14.4 mm. long, compared with 13.2 mm. in *P. pedionomus*. P_2 is absent.

Felis sp. indet.

Loc. V5322: SDSM 5378, isolated I^3, associated left P^{3-4}, and a right M_1 of a small cat about the size of a lynx. All of these teeth were found in place within a distance of not more than three linear inches.

It should not be surprising to find a cat the size of *Lynx rufus* in the lower Pliocene. All felids of Clarendonian age, heretofore, have been of the large variety. This specimen extends the range of *Felis* to the lower Pliocene of North America as it is in Europe.

I^3: bicuspid with a distinct notch separating the cusps; externally, the notch is not so pronounced. P^3: narrow; cingulum indistinct; posterior accessory cusp small; small heel present; deep groove on antero-lingual face of principal cusp. P^4: slightly larger than in *Lynx rufus;* deuterocone broken off, root elliptical in shape; parastyle reduced to a small but distinct cingulum; paracone-metacone blade straighter than in *L. rufus;* internal cingulum on metacone well developed. M_1: slightly larger than in *L. rufus;* talonid absent.

The absence of the talonid in M_1, plus the similarities to *Felis* in the other teeth, demonstrate the validity of assigning this specimen to *Felis*. In specimens with *Felis*-like characters, Macdonald (1954) distinguished *Pseudaelurus* and *Felis* on the presence or absence of the M_1 talonid.

Carnivora fam. indet.

Loc. V5325: SDSM 53107, a right astragalus measuring 47.7 mm. in length and 31.4 mm. in width, is eroded in several critical areas. It is possibly referable to the Felidae, in which case it might belong to *Pseudaelurus*. SDSM 53109, a fragment of left mandible with roots of two premolars, is about the size of a small *Aelurodon*.

Loc. V5324: SDSM 53159, two distal ends of rather slender metapodials are either felids or canids.

Order Proboscidea
Family Gomphotheriidae

Fragments of gomphothere teeth were seen at nearly every locality but were not collected.

Measurements in millimeters
Pliogale manka, SDSM 5372

Length P_1–P_4	15.3	
Length M_1–M_2	11.5	
P_1, antero-posterior diameter	1.4	approximately
P_1, transverse diameter	1.0	approximately
P_2, antero-posterior diameter	2.5	approximately
P_2, transverse diameter	1.4	approximately
P_3, antero-posterior diameter	4.4	approximately
P_3, transverse diameter	1.7	alveolus of posterior moiety
P_4, antero-posterior diameter	5.3	
P_4, transverse diameter	2.0	posterior moiety
M_1, antero-posterior diameter	8.4	
M_1, transverse diameter	3.3	
M_1, talonid, antero-posterior diameter	2.2	
M_1, talonid, transverse diameter	2.6	
M_2, antero-posterior diameter	2.3	alveolus
M_2, transverse diameter	1.3	alveolus

? AMEBELODON sp. indet.

Loc. V521: SDSM 487, left and right rami with left and right M_3 and a left M^3. This specimen is not as complete as the one from Big Spring Canyon discussed by Gregory (1942). It is an old adult. The first two ridges of M_3 are worn flat. There are $5\frac{1}{2}$ ridges altogether. M^3 also has $5\frac{1}{2}$ ridges but is so worn as to be devoid of any useful characters. The right mandible is crushed laterally. The lateral ridges of the symphysis are rounded. A small portion of the right incisive canal is preserved. It is extremely flattened but some of this is the result of crushing.

Measurements in millimeters
? *Amebelodon* sp., SDSM 487

Width of crests of symphysis at narrowest point	70
Depth of jaw in front of M_3	127
Width of symphysis in front of mental foramen, bottom	161
Width of symphysis in front of mental foramen, top	150
Length of right M_3	186
Index of right M_3	37
Width of right M_3 at third ridge (approximate)	70
Length of left M_3	185
Index of left M_3	37
Width of left M_3 at fourth ridge	68

Order PERISSODACTYLA
Family EQUIDAE
NANNIPPUS cf. N. GRATUS
Text-fig. 8A

Loc. V525: SDSM 52104, right mandible with P_2–M_3. Teeth not much worn; approximates the size of *N. gratus* (Leidy) and *N. niobrarensis* (Gidley). If any pli caballinids were present they have been removed by wear. The shape of the mandible below the premolars is similar to that of *N. gratus* (AMNH 10845; Osborn, 1918, fig. 142). P_2–M_3, 124.6 mm.; P_4, A-P, 22.4 mm.; Tr, 11.6 mm. M_1, A-P, 19.1 mm.; Tr, 12.6 mm.

Loc. V529: SDSM 52105, left mandible with P_2–M_2. Cement present; premolars with pli caballinids, most strongly developed in P_4. Teeth narrower and longer than in SDSM 52104 but outline of enamel pattern generally the same. P_4, A-P, 23.0 mm.; Tr, 11.1 mm. M_1, A-P, 22.2 mm.; Tr, 10.5 mm.

Loc. V5324: SDSM 53461, M_3; heavily cemented: A-P, 21.0 mm.; Tr, 9.4 mm.

TEXT-FIG. 8.—A. *Nannippus* cf. *N. gratus*. Left upper cheek tooth, SDSM 53130, ×3/4. B. *Neohipparion occidentale*. Right M^2 SDSM 53102, ×1. C. *Pliohippus pernix*. Left upper cheek tooth, SDSM 53138, ×1, Drawings by author.

Loc. V5325: SDSM 53105, M_2; heavily cemented: A-P, 19.8 mm.; Tr, 9.8 mm.

Loc. V526: SDSM 53111, M_3; cemented, worn: A-P, 22.5 mm., Tr, 10.8 mm.

Loc. V5333: SDSM 5394, P_2; cemented: A-P, 21.0 mm.; Tr, 8.2 mm. M_1; cemented: A-P, 19.0 mm. (approximately); Tr, 10.7 mm. SDSM 5397, P_2; worn A-P, 20.2 mm.; Tr, 11.5 mm.

The above isolated lower cheek teeth are referred to *N. gratus* because of their similarity in size to the cheek teeth in the mandibles (SDSM 52104 and 52105).

Loc. V5330: SDSM 5397, a left M^1 or M^2; protocone suboval, not connected to protoselene; hypoconal groove open; pli caballin present; fossettes fairly complicated: A-P, 19.5 mm.; Tr, 17.6 mm.; length along mesostyle, 28.0 mm.

Loc. V5329: SDSM 53130 (Text-fig. 8A), a left upper cheek tooth; protocone more elongate than in No. 5397; double pli caballin; otherwise the same: A-P, 19.0 mm.; Tr, 14.8 mm.; length along mesostyle, 27.3 mm.

Loc. V5328: SDSM 53137, a left upper cheek tooth, possibly M^2; protocone elongate, isolated; pli caballin present: A-P, 19.0 mm.; Tr, 14.7 mm.; length along mesostyle, 40.6 mm.

Loc. V5335: SDSM 53121, a right upper cheek tooth, probably an M^1; hypostylar groove present; isolated elongate protocone: A-P, 19.3 mm.; Tr, 18.4 mm.; length along mesostyle, 24.6 mm.

These upper cheek teeth are similar to those referred to *N. gratus* from the Big Spring Canyon fauna by Gregory (1942, fig. 48).

NANNIPPUS sp. indet.

Among the teeth belonging to this genus are some upper and lower molars clearly not referable to *N. gratus* or to any *Nannip-*

pus of that size. They belong to some smaller species.

Lower teeth.—Loc. V529: SDSM 5259, a right M_2; covered with cement; no pli caballinid: A-P, 17.2 mm.; Tr, 8.2 mm.

Loc. V5335: SDSM 53120, P_2; no pli caballinid: A-P, 17.5 mm.; Tr, 7.6 mm.

Loc. V5328: SDSM 53140, P_2; no pli caballinid: A-P, 16.5 mm.; Tr, 7.4 mm. SDSM 53139, M_3; unworn; no pli caballinid: A-P, 14.4 mm.; Tr, 6.7 mm.

Loc. V5324: SDSM 53150, P_2; no pli caballinid: A-P, 17.1 mm.; Tr, 7.0 mm.

Loc. V5327: SDSM 53167, P_2; unworn; no pli caballinid: A-P, 17.7 mm.; Tr, 6.0 mm. M_3; unworn: A-P, 17.2 mm.; Tr, 7.1 mm.

Upper teeth.—Loc. V5324: SDSM 53149, right upper cleek tooth, possibly P^4. Isolated hypostylar fossette; protocone not connected to protoselene; pli caballin present. A-P, 17.5 mm.; Tr, 17.0 mm.; length along mesostyle, 40.6 mm. A left upper cheek tooth, possibly P^3; isolated hypostylar fossette; protocone nearly connected to protoselene, protocone more lenticular than in the P^4. A-P, 16.4 mm.; Tr, 15.0 mm.; length along mesostyle, 23.4 mm.

Loc. V5326: SDSM 5374, a left upper cheek tooth, probably P^4. Isolated hypostylar fossette; elongate protocone not connected to protoselene; pli caballin present. A-P, 17.7 mm.; Tr, 16.5 mm. (broken); length along mesostyle, 28.7 mm.

Loc. V529: SDSM 52117, an unworn right M^3 that has been sectioned. Protocone nearly lenticular; pli caballin present. A-P, 16.5 mm.; Tr, 13.3 mm. SDSM 52109, a fragment of upper cheek tooth, with the protocone not as flattened as in No. 52117; faint pli caballin.

Loc. V5333: SDSM 5393, a left upper cheek tooth, possibly P^3 or P^4, is similar to the others. A-P, 17.7 mm.; Tr, 14.7 mm.; length along mesostyle, 38.2 mm.

Loc. V5335: SDSM 53463, a right upper cheek tooth, probably P^4. Isolated hypostylar fossette; protocone sub-oval, not connected to protoselene; small pli caballin. A-P, 18.0 mm.; Tr, 16.9 mm.; length along mesostyle, 39.7 mm.

NANNIPPUS sp. indet.

Loc. V526: SDSM 52107, a fragment of left mandible with DP_{2-4}, apparently belongs here.

Loc. V5334: SDSM 53168, a distal half of a metapodial, is typically nannippine.

NEOHIPPARION OCCIDENTALE (Leidy)
Text-fig. 8B

Loc. V526: SDSM 5256, external half of right M^1 or M^2. The plications of the fossettes compare favorably with those of the type. SDSM 52134, external half of a left molar, is also similar. SDSM 52115, an isolated lenticular protocone, evidently belongs here.

Loc. V529: SDSM 5252, external half of left P^4.

Loc. V5325: SDSM 53102, (Text-fig. 8B) a right M^2, is very similar to the type but slightly smaller.

Loc. V5324: SDSM 53146, four isolated upper cheek teeth of different individuals, all have flattened lenticular protocones.

Loc. V5333: SDSM 5392, two isolated, incomplete upper cheek teeth.

Loc. V5329: SDSM 53128, a left M^1; unerupted.

Loc. V527: SDSM 53114, a DP^3.

Loc. V5328: SDSM 53141, a DP^3.

These last two teeth are similar to those in the milk dentition of *N. occidentale* figured by Gregory (1942, fig. 46).

NEOHIPPARION sp. indet.

The isolated teeth referable to this genus are not specifically determinable.

Loc. V522: SDSM 52110, a deciduous lower cheek tooth, is referred here because of the large rounded widely separated metastylid and metaconid. A small fossettid lies between the hypoconid and protoconid. SDSM 52153, isolated right M_2 and M_3, probably of one individual.

Loc. V525: SDSM 52113, left M_{1-2}; unworn.

Loc. V527: SDSM 5277, right M_{1-2}.

Loc. V529: SDSM 52111, right M_1.

Loc. V5325: SDSM 53103, left M_2 and M_3.

Loc. V5327: SDSM 53166, right M_3 with very small pli caballinid.

Loc. V5329: SDSM 53131, right P_3, with very strong pli caballinid.

Loc. V5332: SDSM 5379, right P_4, SDSM 53112; left M_2.

Loc. V5324: SDSM 53147, six isolated teeth.

Loc. V5330. SDSM 5386, left M_3.

PLIOHIPPUS (ASTROHIPPUS) MARTINI (Hesse)
Text-fig. 9

Loc. V5329: SDSM 53129, an isolated upper cheek tooth. A-P, 18.8 mm.; Tr, 20.3 mm. No pli caballin is present nor is there any cement on the tooth. The posterior fossette is crenulate as in M^1 of the type. SDSM 53122, a lower cheek tooth, is doubtfully referred here. The metaconid and metastylid are of unequal size but separated. The tooth does not seem to be referable to any other genus and is placed here chiefly because of its size.

Loc. V5335: SDSM 53123 (Text-fig. 9), an upper cheek tooth. A-P, 14.5 mm.; Tr, 15.4 mm. A very small pli caballin is present. The fossettes are crenulate as in P^3 or P^4 of the type. Cement is present.

Loc. V5324: SDSM 53151, a worn right P^2, is very similar to that of the type.

So far as I have been able to determine, these teeth are the only record of this species other than those of the type locality.

The upper teeth of so small a species of *Pliohippus* as this, or of worn *Nannippus* teeth in which the protocone is connected to the protoselene may be distiguished from *Calippus* in the following character. The fossettes in *Calippus* are elongate or compressed laterally. In the other genera, the fossettes are deep laterally. In addition, Gregory (1942) called attention to the fact that in worn teeth of *Nannippus* the hypoconal groove becomes isolated as a fossette. In *P. martini*, the hypoconal groove disappears with wear as it gradually pinches out toward the base of the tooth.

PLIOHIPPUS PERNIX Marsh
Text-fig. 8C

Upper teeth.—Loc. V5324: SDSM 53145, four isolated cheek teeth.

Loc. V529: SDSM 53172, worn cheek teeth. SDSM 5253, unworn cheek tooth. SDSM 5148, two fragments of cheek teeth.

Loc. V5328: SDSM 53138 (Text-fig. 8C), cheek tooth.

Loc. V5332: SDSM 5380, cheek tooth.

These teeth are referred to *P. pernix* Marsh rather than to *P. supremus* (Leidy) for the following reasons. In comparing with the type figures of *P. supremus* and with referred specimens from the Burge fauna (McGrew, 1938) and with the type figure of *P. pernix* and referred specimens from Big Spring Canyon (Gregory, 1942), these distinctions, in addition to those made by Gregory are noted.

TEXT-FIG. 9.—*Pliohippus (Astrohippus) martini.* Left upper cheek tooth. SDSM 53123, ×3/4.

In *P. supremus*, the parastyle in the upper premolars is not quite as large nor as flat on the antero-labial corner. The mesostyle in *P. supremus* is more pinched in worn teeth. No pli caballin or fossette plications are present in worn teeth. This latter character is also found in the teeth of the type of *P. pernix* but this specimen has extremely worn teeth. It appears that the pli caballin and plications of the enamel in the fossettes disappear sooner in *P. supremus* than in *P. pernix* teeth with comparable wear.

Lower teeth.—Loc. V5324: SDSM No. 53174; fragment of right mandible with P_2–M_2 and left mandible with P_2 and anterior half of P_3. This jaw compares well in size with that of the type. Although the teeth are much worn, enough of the metaconids and metastylids remain, especially in M_2, to demonstrate that they are large in comparison with the remainder of the tooth and are more rounded than those in *P. supremus*.

Loc. V526: SDSM 53110, premolar.

Loc. V5328: SDSM 53142, premolar.

Loc. V5326·SDSM 5376, three premolars.

Loc. V527: SDSM 53115, molar.

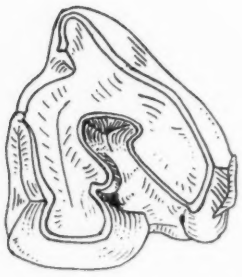
Loc. V5325: SDSM 53104, two molars.

Loc. V5324: SDSM 53148, a premolar and an M_3.

Loc. V529: SDSM 5258, miscellaneous cheek teeth.

PLIOHIPPUS sp. indet.

Loc. V5333: SDSM 5395; fragment of upper cheek tooth. Several teeth from two localities other than the above specimen are



TEXT-FIG. *10.*—*Teleoceras* cf. *T. fossiger*. Left M^3, SDSM 53178, $\times\frac{1}{2}$.

referable to this genus but certain differences are noted which exclude them from *P. pernix*. They are all considerably worn and there is little in the enamel pattern to distinguish them specifically. Their chief characters are a much smaller parastyle that is not flattened on the antero-labial corners and small size. The largest of these teeth is the size of *P. pernix* in cross section but the remainder are smaller.

Loc. V525: SDSM 53113, right P^3, M^{2-3}, and left P^2.

Loc. V5324: SDSM 53464, two upper cheek teeth.

Osborn (1918, fig. 107) referred a specimen from Big Spring Canyon to *Calippus placidus* (Leidy) calling it the neotype (AMNH 10830). This specimen is erroneously referred. The teeth are twice the size of those of Leidy's type and paratypes. It appears to be badly worn specimen of *Pliohippus pernix* very similar to the type of that species. They are both the same size. In each, the parastyles are broad and flat on the antero-labial corner, and the mesostyles appear to be similar. Gregory (1942) reports no *Calippus* from Big Spring Canyon.

Family TAPIRIDAE gen. indet.

Loc. V5325: SDSM 53155, fragment of upper cheek tooth with paracone, is referable to this family.

Family RHINOCEROTIDAE
TELEOCERAS cf. T. FOSSIGER (Cope)
Text-fig. 10

Loc. V5333: SDSM 53178 (Text-fig. 10), left and right M^3, left P^4, left M^1 (broken), and left P_2. These teeth are referable to *Teleoceras* rather than to *Aphelops* because of their greater height of crown and P^4 is narrow in relation to the molars. P_2: A-P, 40.0 mm. (broken); Tr, 23.7 mm. P^4: A-P, 42.4 mm.; Tr, 65.6 mm. Left M^3: greatest width, 61.7 mm.; antero-labial corner deeply notched for M^2.

TELEOCERAS sp. indet.

Loc. V5324: SDSM 53175, an astragalus is in the correct porportions for this genus. Greatest width, 79.6 mm.; width across condyles, 68.6 mm.; width across trochlea, 65.0 mm.

Loc. V5335: SDSM 53125, portion of M^2.

Loc. V5530: SDSM 5384, left I^3; A-P, 59.5 mm.; Tr, 29.3 mm. (measured on triturating surface).

Loc. V529: SDSM 5278, right I^3; A-P, 51.3 mm.; Tr, 18.4 mm.

Loc. V527: SDSM 5276, a left humerus, corresponds with the description of *Teleoceras* humeri given by Matthew (1932).

Loc. V5328: SDSM 53176, a distal end of a left humerus belongs to a younger individual than SDSM 5276.

PERACERAS sp. indet.

Loc. V5333: SDSM 5398, fragment of right M^2, lacks antecrochet and crista, crochet small, median valley with small longitudinal ridge.

Loc. V5328: SDSM 53143, fragments of a small upper molar, possibly belong here.

RHINOCEROTIDAE gen. indet.

Loc. V5328: SDSM 53162, left mandible with P_3–M_3; all teeth somewhat broken, belongs either to *Aphelops* or *Teleoceras*, probably the latter.

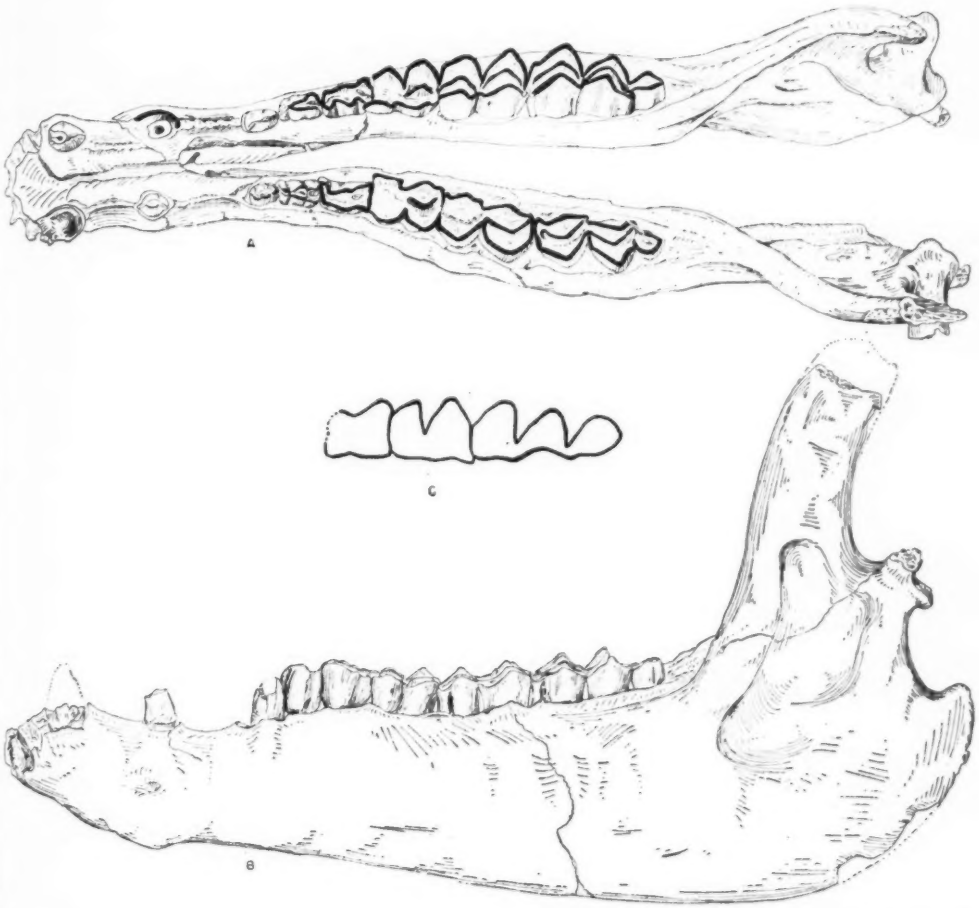
Loc. V5325: SDSM 5399, fragment of lower jaw with roots of premolars, belongs to a rhinoceros the size of *Teleoceras*.

Order ARTIODACTYLA
Family CAMELIDAE
PROCAMELUS DAKOTENSIS, n. sp.
Text-fig. 11A, 11B

Holotype.—SDSM 5281; lower jaws with incisors, left canine and right P_1 missing; 9 lumbar vertebrae, 2 caudal vertebrae, right tibia and cuboid, astragali.

Type locality.—V527.

Diagnosis.—Horizontal ramus longer than



TEXT-FIG. 11—A, B, *Procamelus dakotensis*, n. sp., type specimen, SDSM 5281. A. Occlusal view of jaw, ×½. B. Lateral view of left mandible. Canine outline from right side, ×½. C. *Pliauchenia* cf. *P. magnifontis*, SDSM 52121, ×½. Outline of lower molars. Fig. C by author.

in *Procamelus grandis* Gregory; depth of jaws below molars greater than in *P. grandis;* length P_2–M_3 much greater than in *P. grandis.*

Description.—Incisors missing; canine slightly recurved, worn anteriorly, blade-like posteriorly; P_1 caniniform, less robust than canine, not recurved posteriorly, compressed laterally; P_2 with three distinct lobes, compressed laterally; P_3 narrow, appressed to P_2, anterior lobe directed lingually, wide posterior inflection ("notch" of Gregory, 1942) directed postero-lingually; P_4 with anterior lobe directed lingually almost at right angle to long axis of tooth, posterior inflection isolated as a small fossettid in left tooth, barely open posteriorly in right tooth; M_{1-3} typically cameloid, mesostylids reduced in M_{1-2}.

Comparison.—At first glance, *P. dakotensis* appears to be the same as *P. grandis* Gregory (Big Spring Canyon, South Dakota) but a comparison of measurements displays entirely different proportions in the lower jaws of the two species. The type and paratypes of *P. grandis* show some variation in measurements but a ratio of these is consistently different from the ratio of comparable measurements in *P. dakotensis.*

P. dakotensis is similar to *P. grandis* in

TABLE 3. COMPARISON OF *Procamelus* SPECIMENS

	Height of vertical ramus vs. depth at M_3	Height of vertical ramus vs. depth at M_1	M_{1-3} vs P_{2-4}
P. dakotensis	.4	.272	.56
P. grandis (type) UC No. 32846	.32	.214	.402
P. grandis UC No. 32301	.32	.187	.401
P. grandis UC No. 32589	.32	.210	.444

that it lies in that group of procamelids with narrow blade-like premolars.

The right tibia is shorter than the shortest tibia referred to *P. grandis*. Measurements of the head and distal ends are of no value as the bone is considerably crushed. The astragalus associated with the tibia is, however, not crushed at all. Its width approximates that of the smallest astragali of *P. grandis*, but its length is about 10 mm. greater.

The axis is greatly distorted; third (?) cervical, is also distorted. Both of these vertebrae are shorter than the corresponding elements in *P. grandis*. The remaining vertebrae are not significant.

Referred material.—Loc. V5323: SDSM 53163, fragment of right mandible with P_1–M_2, and anterior moiety of M_3. This specimen is closer to *P. dakotensis* than to *P. grandis* in the premolar measurements. It differs from the type of *P. dakotensis* in the shallower depth of the jaw in front of M_1 and in having a shorter diastema between P_1 and P_2.

Loc. V528: SDSM 5282, a left M^1 or M^2, is not significant. Considerable limb material, all presumably from one individual, is stouter than comparable bones of the type but smaller than referrred specimens of *P. grandis*. These are: right radio-ulna (incomplete, both ends present); left metacarpal, magnum, unciform, trapezoid, cuneiform, lunar, and phalanges; left femur and patella, metatarsal (proximal half only), calcaneum, astragalus, cuboid, navicular, and ectocuneiform.

The metacarpal is smaller than the smallest referred metacarpal of *P. grandis*. The phalanges are shorter but nearly as stout as the referred *P. grandis* (UC 32316) and shorter and smaller than the remainder of the referred *P. grandis* phalanges. The femur is smaller than the femur of *P. grandis*. It is similar in shape except in the medial

TABLE 4.—MEASUREMENTS IN MILLIMETERS

	Procamelus dakotensis SDSM 5281	SDSM 53163	*Procamelus grandis* UC 32864*	UC 32589*
Height vertical ramus	220		228	195
Depth at posterior end of M_3	88		73.5	63
Depth in front of M_1	60	48	49	41
Length diastema, C–P_1	25		34	26
Length diastema, P_1–P_2	33	27	37	29.3
Length, P_2–M_3	160		146	144
Length, P_2–P_4	64	57.8	41.4	43.8
Length, M_1–M_3	114	114	102.9	98.5
Canine, antero-posterior diameter	7.8		10.9	14.7
Canine, transverse diameter	6.4		6.6	7.7
P_1, antero-posterior diameter	11	12.2	8.2	11.5
P_1, transverse diameter	7.8	8.0	5.0	6.7
P_2, antero-posterior diameter	11.4	10.6	7.9	10.7
P_2, transverse diameter	6.2	6.5	5.7	5.0
P_3, antero-posterior diameter	17.2	15.7	12.5	12.3
P_3, transverse diameter	9.0	7.3	7.1	6.3
P_3, antero-posterior diameter	19.8	20.7	15.1	17.8
P_4, transverse diameter	11.7	10.0	10.3	8.8

* Type and paratype of *P. grandis*, University of California; SDSM specimens, type and referred specimen of *P. dakotensis*. All measurements of *P. grandis* from Gregory (1942).

condyle which is smaller than the lateral in *P. dakotensis*. The patella is generally narrower than in *P. grandis*. The metatarsal, calcaneum, and astragalus are generally longer and stouter in *P. grandis* with the exception of the astragalus which is larger in *P. dakotensis*.

PROCAMELUS cf. P. OCCIDENTALIS

Loc. V528: SDSM 52119, a fragment of left mandible with P_2–M_1 with worn dentition, is close in size to the type of this species.

The type of *P. occidentalis* comes from the "sands of the Niobrara River" and referred specimens from the "Little White River," according to Leidy (1869).

PLIAUCHENIA cf. P. MAGNIFONTIS
Text-fig. 11C

Loc. V529: SDSM 52121, fragment of right mandible with worn M_{1-3}. The molars increase rapidly in size from M_1 to M_3. This is similar to the worn dentition referred to *P. magnifontis* by Gregory (1942, fig. 27) from Big Spring Canyon. The increase in size in the molars is much more rapid in the Wolf Creek specimen.

	SDSM 52121 mm.	UC 33448 mm.
M_1, antero-posterior diameter	16	18.2
M_2, antero-posterior diameter	21	20.5
M_3, antero-posterior diameter	38.7	29.5

Loc. V521: SDSM 52106, left and right maxillary fragment with right P^3 and left P^{3-4}. All the teeth are greatly worn. The absence of P^2 eliminates this specimen from other genera of comaprable size.

PARACAMELUS sp. indet.

Loc. V5330: SDSM 5385, a right upper cheek tooth; A-P, 41.3 mm.; Tr, 28.0 mm.

Loc. V5325: SDSM 5369, proximal end of a radio-ulna, distal portion of a tibia, distal end of a fibula, one phalanx (all probably from one individual). The massiveness of these fragments indicates *Paracamelus* rather than *Alticamelus*.

CAMELIDAE gen. indet.

Loc. V529: SDSM 5260, a left M_3; A-P, 43.6 mm.; Tr, 16.8 mm.

Loc. V5333: SDSM 5396, a left M_3; A-P, 35.3 mm.; Tr, 11.0 mm.

Loc. V527: SDSM 53116, a right M_2: A-P, 35.4 mm.; Tr, 18.3 mm.

Loc. V5336: SDSM 5388, a left P_3; slightly worn: A-P, 21.6 mm.; Tr, 10.6 mm. An unerupted P_3: A-P, 22.0 mm.; Tr, 11.6 mm.

Loc. V521: SDSM 5149, fragment of right maxilla with canine and P^1.

Loc. V5335: SDSM 53118, left M^{1-2}. M^2: A-P, 28.7 mm.; Tr, 18.4 mm. Ribs prominent; teeth narrow transversely.

Loc. V5324: SDSM 53154, three isolated upper cheek teeth. Largest tooth: A-P, 32.9 mm.; Tr, 20.0 mm.

Loc. V5336: SDSM 5389, fragment of upper cheek tooth.

Loc. V5328: SDSM 53134, isolated P^4 and fragment of maxilla with canine.

Loc. V525: SDSM 5382, fibula.

Loc. V5334: SDSM 53169, proximal end of metapodials. Length across condyles, 44.4 mm.

Loc. V5326: SDSM 5377, proximal end of metapodials (one condyle missing). Approximate length across condyles, 83.0 mm.

Loc. V5325: SDSM 53108, one astragalus, one fibula, and one cuboid; all larger than those referred to *P. dakotensis*. Astragalus: greatest length, 67.6 mm.; width head, 44.5 mm.; width trochlea, 38.0 mm.

Loc. V5329: SDSM 53173, two isolated astragali (one broken). Greatest length, 58.3 mm.; width

	Measurements in millimeters *Leidy's specimen No. 1 (p. 152)	No. 2 (p. 153)	SDSM 52119	Leidy's No. 5
P_4, antero-posterior diameter	16.9		16.4	16.9
P_4, transverse diameter			10.6	8.48
M_1, antero-posterior diameter	22.2		23.5	21.2
Depth below P_4		33.9	38.7	

* Leidy 1869.

Measurements in millimeters
Procamelus dakotensis

Humerus

	SDSM 5282	*P. grandis*
Total length	338.0	
Diameter across condyles	60.6	63.0
Length from head to condyles	265.0	350.0

Radio-ulna

	SDSM 5282	UC 32301c*
Length	435.0	
Length, sigmoid notch-distal end	380.0	425.0
Width, distal end of sigmoid notch	50.3	60.0
Width, distal end	53.0	57.0

* Smallest of the referred *P. grandis*.

Metacarpal

	SDSM 5282	UC 32316*
Length	355.0	370.0
Width of head	52.5	43.2
Width distal end	61.5	76.0
Width center of shaft	29.6	33.0

* Smallest of the referred *P. grandis*.

Femur

	SDSM 5282	UC 33449
Length	407.0	470.0
Diameter across condyles	80.5	76.0–86.5*
Length patellar trochlea	56.4	52.0–60.0†

* UC No. 33452.
† UC No. 33453. UC specimens, *P. grandis*.

Patella

	SDSM 5282	UC 32301*	UC 32316†
Length	66.6	76	63
Width at center	31.1	38	36.5

* Type, *P. grandis*.
† Referred, *P. grandis*.

Tibia

	SDSM 5281	UC 32301*
Length	390	430–480
Width distal end	37	
Length of head	87	
Width of head	36	

* Largest and smallest referred *P. grandis*.

Metatarsal

	SDSM 5282	UC 25487*	UC 32301*
Width of head	44.7	45.0	53.4
Width middle of shaft	26.5	27.0	32.0

* Largest and smallest *P. grandis*.

Calcaneum

	SDSM 5282	UC 32325*	UC 32301*
Length	120.0	111.0	135.0

* Largest and smallest *P. grandis*.

Procamelus dakotensis (*continued*)

Astragalus

	SDSM 5282	SDSM 5281	UC 29548b*	UC 32325a*
Length	56.0	53.4	43.5	45.0

* Largest and smallest *P. grandis*.

Proximal phalanges

	SDSM 5282		UC 32316		UC 32325c	UC 32301	UC 34391*
	medial	lateral	medial	lateral			
Length	87.5	88.4	100	94.7	103.1	98	95.5
Width proximal end	28	28.8	29.7	28.5	32.7	34.7	
Width middle of shaft	15	16	16.5	15	17.1	17.9	18.5
Width distal end	23	24.6	20.8	24.3	29.7	26.5	27.8

* UC specimens, *P. grandis*.

Axis

	SDSM 5281	UC 32301*
Length	150.0	170.0

* Referred *P. grandis*.

trochlea, 36.0 mm.

Loc. V527: SDSM 53117, astragalus. Greatest length, 53.0 mm.; width head, 36.4 mm.; width trochlea, 37.6 mm.

Loc. V521: SDSM 52118, astragalus. Greatest length, 59.0 mm.; width head, 36.6 mm.; width trochlea, 36.5 mm.

Family Palaeomerycidae

Parablastomeryx sp. indet.

Loc. V5324: SDSM 53156, a right upper molar larger than any of the molars in *P. gregorii* Frick or *P. galushi* Frick, but otherwise similar. A-P, 18.0 mm.; Tr, 16.4 mm.

Longirostromeryx wellsi (Matthew)

Loc. V5334: SDSM 53171, fragment of left mandible with M_{2-3}. These teeth are very close to those of this species from Big Spring Canyon although M_3 appears to be a little shorter in length in the Wolf Creek specimen. The external stylids are strongly developed. M_2: A-P, 9.8 mm.; Tr, 6.3 mm. M_3: A-P, 12.4 mm.; Tr, 5.8 mm.

Cranioceras cf. C. dakotensis

Loc. V5327: SDSM 53165, fragment of right mandible with roots of P_2 and P_3–M_1 complete. The teeth in this specimen are very worn and may even belong to another palaeomerycid. Length P_2–P_4, 38.5 mm.; P_4: A-P, 14.0 mm.; Tr, 9.0 mm. M_1: A-P, 18.0 mm.; Tr, 11.4 mm.

Palaeomerycidae gen. indet.

Loc. V521: SDSM 5270; fragment of upper cheek tooth.

Loc. V5325: SDSM 53100; fragment of upper molar.

Family Antilocapridae

Merycodus (?) furcatus (Leidy)

Loc. V524: SDSM 52114, fragment of right mandible with posterior half of P_4 and complete M_1. M_1: A-P, 9.2 mm.; Tr, 4.6 mm.

Loc. V523: SDSM 5265, right M_1: A-P, 10.1 mm.; Tr, 4.7 mm.

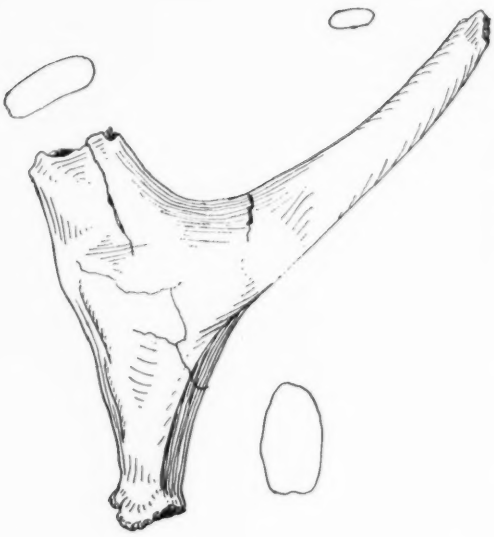
Loc. V529: SDSM 5279, left M_3 with posterior lophid missing. A-P (approximate), 12.7 mm.; Tr, 4.5 mm.

Loc. V521: SDSM 5274, two isolated worn cheek teeth.

Loc. V5324: SDSM 53158, a jaw fragment with left unworn M_3. A-P, 12.5 mm.; Tr, 5.1 mm. A more worn M_2: A-P, 11.4 mm.; Tr, 4.9 mm. An astragalus; greatest length. 20.1 mm.; width head, 11.7 mm.; width trochlea, 10.9 mm.

Loc. V5328: SDSM 53136, fragment of left mandible with M_{1-2}. M_2: A-P, 10.3 mm.; Tr, 5.3 mm.

Loc. V5335: SDSM 53126, right M_3: A-P, 16.0 mm.; Tr, 6.2 mm. There are no styles or ribs on this tooth. However, it is greatly worn.



TEXT-FIG. *12.*—*Meryceros* cf. *M. major*. SDSM 5381, ×¼. Horn core.

Horn Cores

Loc. V5324: SDSM 53157.
Loc. V5326: SDSM 5373.
Loc. V5328: SDSM 53135.
Loc. V5336: SDSM 5391.

The above horn cores have beams with circular cross sections and all possess burrs.

MERYCEROS cf. M. MAJOR
Text-fig. 12

Loc. V521: SDSM 5381, a right horn core. This specimen is slightly larger than the type of the species figured by Frick (1937, fig. 39A, F: AMNH 31439). Length of beam from center of bow to base (from outside), 80.3 mm. Width across tines at base of bow, 77.6 mm. The tines are compressed laterally, the anterior tine greatly so. The upper portion of the beam is also compressed laterally but toward the base this compression is shifted to an antero-posterior position. The anterior tine turns medially. A small rugosity about 20 mm. up from the base indicates that a burr may have been present during life.

Gregory (1942) does not recognize *Meryceros* on the assumption that the horn cores of *Meryceros* from the Niobrara River fauna represent the horn of *Merycodus necatus* dentition from the Bijou Hills fauna. While this may be true, it is risky at best and it seems more logical to me to retain *Merycodus* for those antilocaprids with horn cores having burrs with beams and tines circular in cross section and *Meryceros* for those species with compressed tines and beams with no or a small burr. The final solution must actually await the discovery of associated dentition and horn cores of *Merycodus necatus* in the Bijou Hills fauna.

ANTILOCAPRIDAE gen. indet.

Loc. V5335: SDSM 53124, distal end of a metapodial.

ARTIODACTYLA fam. indet.

Loc. V5325: SDSM 53106; a proximal phalanx belonging to a small articodactyl.

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A BIBLIOGRAPHY OF THE ORDER STROMATOPOROIDEA

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ABSTRACT—The class Hydrozoa is considered to include the orders Stromatoporoidea (Ord.-Dev.), Sphaeractinoidea (Perm.-Cret.), and Hydroidea (Cret.-Rec.). The bibliography of the Stromatoporoidea embraces 502 titles.

INTRODUCTION

In our studies on the order Stromatoporoidea, we have found it necessary to compile a complete bibliography of the subject. Useful bibliographies are given by Kühn (1928, pp. 1–24, and 1939, pp. A62, A63) and by Lecompte (1952, pp. 332–351). Former bibliographies lack many of the Russian articles and some of the more obscure articles which we have tried to include, and they also contain references to organisms which are not Stromatoporoidea. We do not consider the so-called stromatoporoids occurring above the Devonian to belong to the order Stromatoporoidea, but to the order Sphaeractinoidea, nor do we include references to the order Hydroidea.

Fossils in the Class Hydrozoa include: (1) the order Stromatoporoidea, skeleton calcareous, composed of imbricating, arcuate plates, or of laminae, radial pillars and arcuate plates, and have astrorhizae, Ordovician to Devonian; (2) the order Sphaeractinoidea, skeleton calcareous, composed of concentric and radial trabeculae, making an open network, with astrorhizae, Permian to Cretaceous; and, (3) the order Hydroidea, skeleton calcareous, mat-like (*Hydractinia*), or upright, porous (*Millepora, Stylaster*), without typical astrorhizae, Cretaceous to Recent.

We have included papers dealing with stromatoporoids from the European Etroeungt formation, a calcareous, marine zone, which has been considered to be transitional from the uppermost Devonian to the basal Carboniferous, and other equivalent horizons. Several of the more significant references to stromatolites are included, because of their superficial resemblance to stromatoporoids, with which they may occur, and also a reference to the work by H. N. Moseley on the Recent milleporoids collected by the *Challenger* Expedition, because of the excellence of illustrations of hydrocoralline morphology, and because Moseley therein coined the term coenosteum, for the calcareous hydroid skeleton.

The page citations are not to the inclusive article but refer to the pages on which a discussion or reference to the stromatoporoids appears with the exception of those papers which we have not seen, in which cases the page citations are to the complete article.

Though the literature seems voluminous, considering the obscurity and lack of knowledge of the stromatoporoids, few papers deal exclusively with the stromatoporoids, and only a few are of any value for purposes of identification or comparison. For the identification of North American species, only the works of Nicholson and Parks are of great value. We have found it necessary to consult the works on foreign stromatoporoids, for a few species appear to be common to North America and other continents. The works of the following foreign students have proved to be most useful: Gorsky, Kühn, Lecompte, LeMaître, Nicholson, Ozaki, Počta, Riabinin, Ripper, Yabe & Sugiyama, Vinassa de Regny and Yavorsky. Most of the works are of a stratigraphic nature, in which the stromatoporoids occur as a name in a faunal list along with other invertebrate fossils. Such references are included because they are of value in finding known stromatoporoid localities, give information concerning ranges and distributions of species, and contain some ecological information. The disadvantage is that one must accept the authors' identifications without opportunity for verification. The volume and diversity of literature is a good indication of the widespread occurrence and abundance of the stromatoporoids.

The long-neglected stromatoporoids are

due for a revival of study. Since stromatoporoids occur in Paleozoic reefs, and because petroleum is associated with Paleozoic reefs or bioherms, we hope to make the stromatoporoids of practical use as a stratigraphic aid. Few stromatoporoids have been described from North America, and many species are new.

We have made a serious attempt to see as many of the articles as possible, though much of the literature is old and in journals difficult to obtain. The library of a large university is likely to contain scarcely half of the references on Stromatoporoidea. We have so far seen 356 of the 502 references in the bibliography. The articles we consider to be of taxonomic or stratigraphic importance are indicated by author's name in boldface type. Articles we have not consulted are marked with an N.

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A NEW CLARENDONIAN MAMMALIAN FAUNA FROM THE TRUCKEE FORMATION OF WESTERN NEVADA

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ABSTRACT—A new mammalian fauna from the Truckee formation is described, and a short review of the previous finds from this formation is given. The Nightingale Road fauna is correlated with the Chalk Springs fauna from Elko County, Nevada, and with the Black Hawk Ranch fauna from Contra Costa County, California. A new aplodontid, *Pseudaplodon occidentale*, n. sp., and a new camel, *Aepycamelus bradyi*, n. sp., are described. A new name, *Aepycamelus*, is proposed for those species now referred to *Alticamelus*.

INTRODUCTION

THE following article describes a new late Clarendonian fauna (the Nightingale Road fauna) from the Truckee formation of western Nevada. My attention was first directed to this locality by members of the Department of Geology of the University of Nevada while I was visiting their summer field camp in Elko County. They referred me to Mr. and Mrs. R. E. Brady of Brady's Hot Springs who had collected several *Neohipparion* teeth along the road to Nightingale, about 10 miles north of the hot springs. The major portion of the collection was made in a few days during the summer of 1948 by the author and Messrs. Willis J. Pelletier and Henry T. Herlyn. Subsequent weekend field trips produced a small amount of additional material.

The locality and specimen numbers are all those of the University of California Museum of Paleontology.

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[1] The major portion of this article was written while the author was with the University of California Museum of Paleontology.

HISTORY OF THE TRUCKEE FAUNAS

In his report on the Fortieth Parallel Survey, Clarence King (1878) described the Truckee group and reported the occurrence of a rhinoceros tooth from the Kawsoh Mountains. This tooth, in conjunction with a fauna of fresh water Mollusca from Fossil Hill, led King to believe that the beds were of Miocene age. Later Buwalda (1914) reported on a proboscidean tooth from the Truckee beds between Reno and Verdi, Nevada. He stated that King's rhinoceros tooth was probably *Rhinoceros* (*Diceratherium*) *pacificus* Leidy and identified his proboscidean tooth as *Tetrabelodon* (?), sp.

Buwalda did not commit himself definitely on the age of the beds, but seemed to favor late Miocene and indicated that the Truckee formation and the Esmeralda might be equivalent. The Stewart Spring fauna, a distinct and older faunal unit, had not been recognized as such at that time; it was included as part of the Esmeralda faunal assemblage and influenced Merriam (1916) in placing it in the late Miocene.

Stirton (1939) reviewed this work and stated that although Buwalda's proboscidean tooth was so fragmentary that a

definite age determination could not be made, it did not greatly differ from the early Pliocene species, "(?) *Trilophodon simpsoni* Stirton" (*Trilophodon* is now considered a synonym of *Gomphotherium*). Stirton also mentions another fauna from the vicinity of Hazen in Churchill County, Nevada. Of this fauna he says,

> Fossils from this locality include numerous fish bones, the patella of a carnivore, and the proximal end of a horse metacarpal. The last mentioned is the only specimen in this collection of importance in correlation. Though it could belong to *Hipparion*, *Neohipparion* or *Pliohippus*, its size alone indicates a Lower or Middle Pliocene stage of development.

Axelrod (1948) refers to the flora from the Hazen area as being of middle Pliocene age on the basis of the floral composition. Further prospecting in the Hazen area for vertebrate remains has yielded only fragments of a rodent and bird bones, which furnish no further evidence for correlation.

A new fauna was collected in 1948 from beds to the northwest of the Hot Springs Mountains. These beds seem to agree lithologically with the Truckee formation as it is now restricted. The fossils were taken from exposures on the east side of the Brady Hot Springs-Nightingale Road between 9 and 10 miles north of its junction with U. S. Highway 40.

A close correlation of these fossils with those from Hazen must await the discovery of more diagnostic remains from Hazen; similarly a correlation cannot be made with the more fragmentary material from the Hot Springs Mountains or Verdi. Due to the distances involved and the conditions of present day desert deposition, the relative stratigraphic position of these deposits cannot be determined.

TRUCKEE FORMATION VERTEBRATE LOCALITIES

V2577. Verdi. "the proboscidean tooth was found in a section of tuffaceous and arenaceous strata, dipping about 30 degrees to the northwest, about three-fourths of a mile southeast of Verdi, Nevada." (Buwalda, 1914).

V3943. Hazen. ". . . about two and one half miles northeast of Hazen, at the base of a gray tuff member near a four- or five-inch band of blue tuffaceous sand. These beds, with a dip of about 11°, occur within, but should not be confused with, the old Lake Lahontan terrace lines." (Stirton, 1939).

V4844. Nightingale. Nine miles north of Brady's Hot Springs on the east side of the Nightingale Road in a small hill of tuffs, shales, and gravels. SE¼ SW¼ Sec. 28, T. 24 N., R. 26 E., Wadsworth Quadrangle, Churchill County, Nevada.

V4845. Brady Pocket. Ten miles north of Brady's Hot Springs and one-half mile east of the Nightingale Road in a series of tuffs, sands, and pebble conglomerates. NW¼ NE¼ Sec. 21, T. 24 N., R. 26 E., Wadsworth Quadrangle, Churchill County, Nevada.

THE NIGHTINGALE ROAD FAUNA

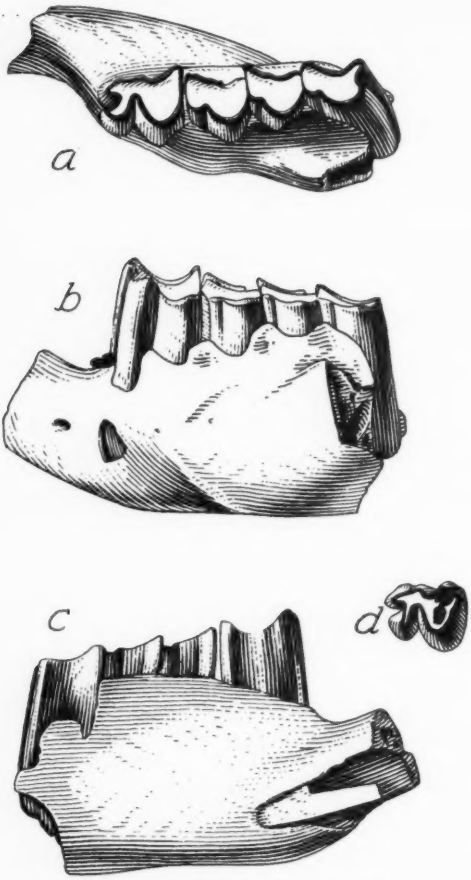
Geology of the Nightingale Road vertebrate localities.—The fossiliferous exposures along the Nightingale Road occur near the head of the valley that extends north from Brady's Hot Springs. The beds at locality V4844 are exposed where they stand out above the valley fill in the center of the valley. The beds at the Brady Pocket are exposed with valley fill on three sides, and to the north they are covered by later basalts which form the hills that wall in the north end of the valley. The Brady Pocket beds are slightly lower stratigraphically than the Nightingale exposures, and are striking N. 20° E., with a SE dip of 25°.

Columnar section at Brady Pocket

	Feet
Blue-white shard crystalline rhyolite tuff	3
Brown argillaceous sand, grains angular to subangular, quartz, biotite, epidote, hornblende crystal fragments	48
Fossiliferous sands and gravels, angular to subangular to subrounded fragments, high in quartz	40
Crystalline shard aphanitic tuffs and clays	38
Sands, clays, and tuffs	25
Tuffs, sands, and clays	50
	204

An unknown thickness of sediments separates these beds from the Nightingale exposures which are composed of sands, gravels, clays and tuffs.

Age of the fauna.—The nature of the mammalian remains from the Verdi, Kawsoh Mountains, and Hazen localities does not permit a close correlation between the



TEXT-FIG. *1—Pseudaplodon occidentale*, n. sp. *a–c*, Holotype, left mandibular fragment, UCMP 38662: *a*, occlusal view; *b*, labial view; *c*, lingual view. *d*, Paratype, left P_4, UCMP 38820, occlusal view. ×3.

strata in these areas, and a range from early to middle Pliocene in age is possible. The materials from these "Truckee" localities may be of the same age but their stratigraphic positions cannot be determined.

The Truckee fauna, as represented at the Nightingale and Brady Pocket localities, may be considered as late Clarendonian in age on the basis of a beaver, *Eucastor* near *E. lecontei* and a dog, *Osteoborus diabloensis* Richey. *Eucastor* and *Osteoborus* are typically Clarendonian genera. These species are common in the Black Hawk Ranch fauna of California. The beaver also is known from a single tooth in the Chalk Springs fauna in Elko County, Nevada. A *Neohipparion* near *N. occidentale* is present in this fauna and is also common in the Chalk Springs fauna as well as in many Clarendonian faunas from the Great Plains. Another *Neohipparion*, much like *N. sinclairi* (Wortman), is found in this fauna and in the Big Spring Canyon fauna of South Dakota.

On the strength of these forms, the fauna may be correlated with the Black Hawk Ranch fauna of California, the Chalk Springs fauna of Nevada, and the Big Spring Canyon fauna of South Dakota.

SYSTEMATIC PALEONTOLOGY

Order LAGOMORPHA

LEPORIDAE, gen. indet.

Locality and specimen.—V4845, Brady Pocket; UCMP 38676, 38796.

Five calcanea and some fragmentary cheek teeth are the only record of this group in the fauna.

Order RODENTIA

Family APLODONTIDAE

PSEUDAPLODON OCCIDENTALE, n. sp.

Text-fig. 1, 2

Type.—Left mandible, UCMP 38662. Fragment of mandible with P_4, M_{1-3}, and root of incisor.

Paratype.—Left P_4, UCMP 38820. Unworn tooth with roots.

Referred material.—Upper cheek tooth, UCMP 38819.

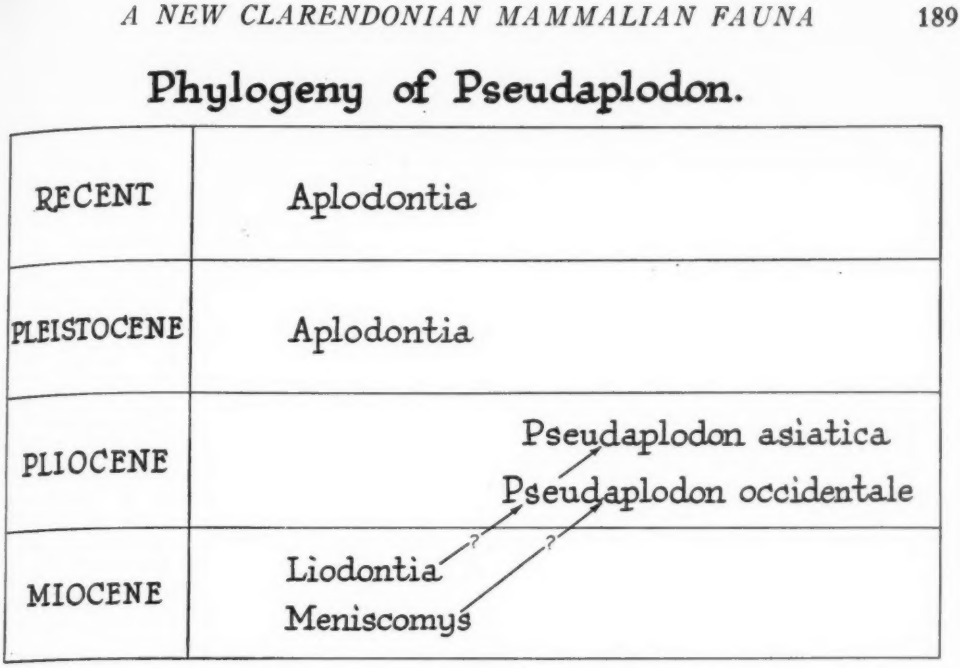
Type locality.—UCMP loc. V4845, Brady Pocket.

Fauna.—Nightingale Road.

Age.—Early Pliocene, Clarendonian.

Diagnosis.—Crown height of cheek teeth above alveolar border 7.0 mm.; M_1 and M_2 subequal in all dimensions. M_3 with greater antero-posterior diameter than M_1 and M_2.

Description.—Lingual wall of lower molars concave with anterior and posterior corners prominent, labial walls convex with small inflections near anterior edge. M_3 with well developed posterior vertical groove. M_2 and M_1 alike. P_4 with labial notch deeply cut and near center of labial wall, anterior moiety prominent with well defined notch on anterior face, antero-lingual corner with spur directed forward, mesostylid faintly indicated, postero-lingual corner with prominent style. Unworn P_4 with four enamel



TEXT-FIG. 2—Phylogeny of *Pseudaplodon*.

lakes, two roots. ?Left M^3 with anterior moeity of lingual wall concave, posterior moiety convex, anterior three-fourths of labial wall well rounded with spur at posterior labial corner formed by a deep inflection.

Measurements (mm.) of *Pseudaplodon occidentale*

Total length of tooth row	12.3
M_3, A-P diam.	2.9
M_3, Tr. diam.	2.1
M_2, A-P diam.	2.5
M_2, Tr. diam.	2.25
M_1, A-P diam.	2.5
M_1, Tr. diam.	2.25
P_4, A-P diam.	3.5
P_4, Tr. diam.	2.5

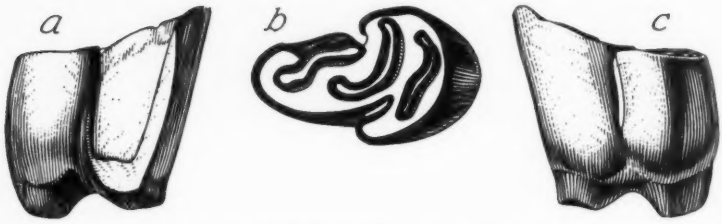
Discussion.—The genotypic species was described as *Aplodontia asiatica* Schlosser (1924) from the Ertemte of Mongolia, based on a mandibular ramus. It is much like the specimen described above. The Nevada species differs from the Ertemte species in having M_1 and M_2 of equal proportions, and an M_3 with a relatively greater antero-posterior diameter than the M_2.

The relationships of the genotypic species have been discussed at length in previous studies of the aplodontids. Miller (1927) proposed the genus *Pseudoplodon* on the basis of Schlosser's description of *A. asiatica*. At the same time, he denied the possibility of this species being an aplodontid and suggested that it was a "*Dipodid*" as represented by *Ctenodactylus*, which is now placed in a different superfamily from the dipodids. He did not recognize the similarity between the Asiatic species and *Liodontia* from the North American Middle Tertiary.

Gazin (1932), while reviewing the genus *Liodontia* Miller & Gidley (1918), compared it with *Aplodontia* (?) *asiatica;* and considered the Ertemte species to be a primitive branch of the aplodont stock, which branched off of the main line during the evolution of *Meniscomys hippodus* Cope into *Liodontia alexandrae* (Furlong).

Friant (1937) reviewed Schlosser (1924) and Miller (1927) and stoutly defended Schlosser's original determination. In 1937, Wilson critically reviewed Schlosser's and Miller's works and showed that *Pseudoplodon* was clearly an aplodontid.

McGrew (1941), in his review of the Aplodontoidea, presents little additional information on *Pseudaplodon*, but does treat briefly with the geologic and geographic distribution of the Aplodontidae. He further points out its peculiar distribution and



TEXT-FIG. 3—*?Hystricops*, left P^4, UCMP 38789: *a*, lingual view; *b*, occlusal view; *c*, labial view. ×2.

apparent lack of radiation, with the exception of the single oriental species.

A comparison of *Pseudaplodon* with *Liodontia* shows a rather close relationship, although no closer than its relationship to *Aplodontia*. The P_4 of *Pseudaplodon* has an inflection on its anterior face which is a variable character in *Aplodontia*. It also has a "mesostylid" which is weakly developed in *Liodontia* but very strong in the Recent genus. The lower molars are similar in both genera with the exception of the concave labial wall and the posterior inflection and strong lingual posterior corner in *Pseudaplodon*. In comparison with *Liodontia*, we find that it has a lingual inflection on P_4 instead of the "mesostylid" and the posterior inflection is lacking on M_3.

Meniscomys could have been a direct ancestor of either *Liodontia* or *Pseudaplodon*, while the latter genus could have developed from *Meniscomys* via *Liodontia*. The "mesostylid" of *Pseudaplodon* may represent the enlargement of the salient between the two inflections on the labial wall of the cheek teeth of *Meniscomys hippodus* Cope or as a secondary development, coupled with the loss of the labial inflection in the teeth of *Liodontia*.

Family MYLAGAULIDAE
MYLAGAULUS sp.

Locality and specimen.—V4845, Brady Pocket; UCMP 38665.

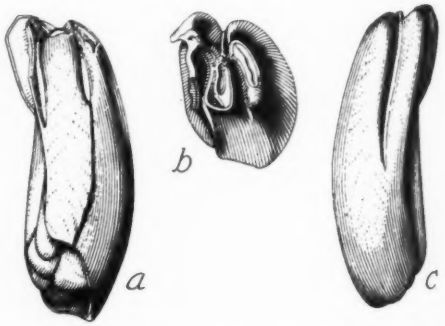
As Wilson (1937) pointed out, there are probably a great many more species and genera of this form than have been described or recognized. In our present state of knowledge most Pliocene specimens of this "genus" are referred to *M. monodon* Cope. It is very likely that the eventual discovery and description of more complete material will increase our understanding of the development and relationships of the animals which form this strange family.

Mylagaulus is represented in this fauna by a single left P_4 from the Brady Pocket. It has six elongated lakes arranged in echelon; three overlapping lakes with posterior borders near the lingual wall of the tooth; two lakes, one behind the other, extending from the antero-labial corner to the center of the posterior wall; and a sixth lake angling across the postero-labial corner. The tooth has an antero-posterior diameter of 11.7 mm. and a transverse diameter of 5.7 mm.

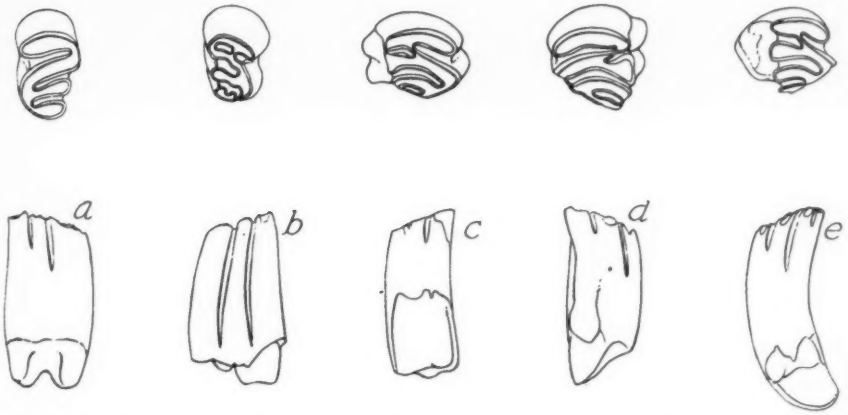
Family CASTORIDAE
? HYSTRICOPS sp.
Text-fig. 3, 4

Locality and specimens.—V4845, Brady Pocket; UCMP 38678, 38789, and 39326.

This form is represented by three isolated cheek teeth. A left P_4 (UCMP 38789) with the antero-lingual quarter broken away shows general similarities in size and shape to Leidy's (1858) type for *Hystricops*



TEXT-FIG. 4—*?Hystricops*, P^4, UCMP 38678: *a*, labial view; *b*, occlusal view; *c*, lingual view. ×2.



TEXT-FIG. 5—*Eucastor* near *E. lecontei*. *a*, P_4, UCMP 39331; *b*, P_4, UCMP 39332; *c*, P^4, UCMP 39333; *d*, P^4, UCMP 39334; *e*, P^4, UCMP 38661. Occlusal and lingual views. ×2.

venustus. As in Leidy's type, this tooth has a slightly irregular metafossettid and posteriorly directed hypoflexid with the hypostriid extending to within 4.0 mm. of the enamel base of the crown. The mesofossettid is crescentic, this condition may be present in the type of *H. venustus* Leidy but, if it were, it could only be seen if the wear on the occlusal surface were extended downward. On the median lingual side of the posterior broken edge there is some indication of a shallow vertical groove as is seen in *Amblycastor*. The parafossettid extends anterolabially to the anterior of the midline of the crown.

A fragmentary lower molar (UCMP 39326) shows a short crescentic parafossettid, a long crescentic metafossettid, the hypostriid extending to the midline of the tooth and a short irregular-shaped mesofossettid in juxtaposition with the end of the hypoflexid. The pattern of the tooth is not greatly different from that of *Amblycastor fluminis* Matthew.

An unworn P^4 (UCMP 38678), with a pattern and size comparable to that of *Trogontherium minus* Newton from the upper Pliocene of England, has a crown height of 21.4 mm., a transverse diameter at the base of the hypoflexus of 9.1 mm. The hypostria extends halfway up the wall of the tooth. The parastria is short and extends only 3.9 mm. above the occlusal surface of the unworn tooth. The mesostria extends an additional two millimeters beyond the termination of the parastria. A small and shallow fossette on the crest is found between the paraflexus and the mesoflexus. The posterior portion of the tooth is broken away.

Discussion.—A comparison with Teilhard de Chardin & Young's (1931) figure of *Chalicomys anderssoni* Schlosser (1924) shows the same occlusal pattern as that of the Nevada specimen. On the other hand, if the Nevada tooth were worn down for 7.0 mm., it might be similar in pattern to the specimen (AMNH 1387), which was described by Matthew & Cook (1909) as *Hystricops* cf. *H. venustus* and later referred to *Amblycastor fluminis* by Matthew in 1918.

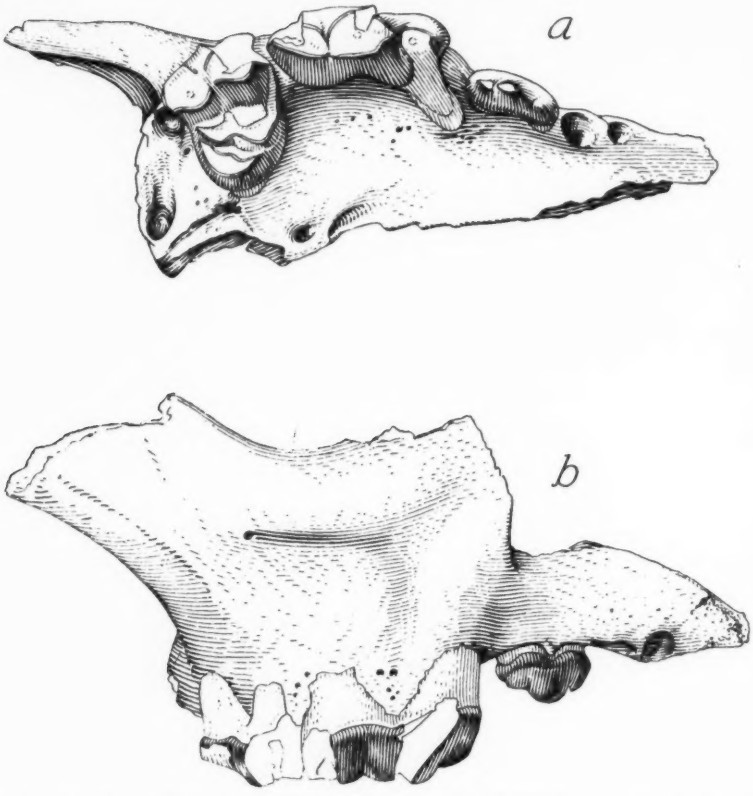
It is not practical to attempt to reach conclusions on the relationships of the material at hand until a more complete review of the castorids is available.

EUCASTOR near E. LECONTEI (Merriam)
Text-fig. 5

Locality and specimens.—V4845, Brady Pocket; UCMP 38661, 39117, 39331–39334, 38787.

Beavers closely resembling *Eucastor lecontei* (Merriam) are known from this fauna and from the Chalk Spring fauna. In 1947, a single tooth was found in the Chalk Spring area and, the following year, 20 teeth were found in the Brady Pocket.

A comparison of these teeth with Stirton's (1935) diagnosis of *Eucastor lecontei* (Mer-



TEXT-FIG. 6—*Osteoborus diabloensis*, right maxillary, UCMP 38666: *a*, occlusal view; *b*, labial view. ×1.

riam), with the material from the Siesta beds (the type locality) in the Berkeley Hills, and with the Black Hawk Ranch fauna shows a close relationship between these two forms.

While possibly not specifically identical, they are so similar that they indicate a very close temporal relationship.

Order CARNIVORA
Family CANIDAE
OSTEOBORUS DIABLOENSIS Richey
Text-fig. 6

Locality and specimen.—V4845, Brady Pocket; UCMP 38666.

A right maxillary (UCMP 38666) with well worn P^3–M^1 and the alveoli for P_2 is indistinguishable from specimens from the type locality on Mt. Diablo, California. A comparison with two maxillaries (UCMP 33477, 33492) and a cranium (UCMP 34515) from the Black Hawk Ranch quarry (Macdonald, 1948, fig. 5, 7) shows that this maxillary falls within the limits of variation for this species.

Richey (1938) stated that the connection of the protocone to the parastyle on the M^1 by a pair of small ridges was characteristic of this species. This feature is lost at an early stage of wear and is lacking in the Nevada specimen.

CANINAE, gen. indet.

Locality and specimen.—V4845, Brady Pocket; UCMP 39410.

The fragmentary mandible of a small dog with an unworn M_2 and the root of a small third molar was the only indication of fox-like carnivores in this fauna. The M_2 is larger than those in specimens of *Vulpes vafer* (Leidy) from the Niobrara River and Ricardo faunas. It is about the same size as the second lower molars that Macdonald (1948, p. 57) described from the Black

Measurements (mm.) of *Osteoborus diabloensis* Richey

	Brady Pocket (38666)	(33477)	Black Hawk Ranch (33492)	(34515)	
M^1, A-P diam.	15.0	15.3	16.9	16.8	16.1
M^1, Tr. diam.	19.1	17.7	19.3	20.0	19.6
M^1, width at base of talon	12.0	11.8	12.7	13.7	13.5
P^4, A-P diam.	24.0	23.6	25.4	26.9	25.7
P^3, A-P diam.	12.5	12.5		14.2	14.6
P^4, Tr. diam.	5.7	5.8		6.7	7.0

Hawk Ranch fauna. The Nevada specimen differs from the Black Hawk Ranch teeth in having a smaller basin on the talonid, and a shorter labial cingulum which does not extend anteriorly to the base of the paraconid. This tooth measures 6.1 mm. by 4.2 mm. and possibly is referable to the genus *Vulpes*.

Family MUSTELIDAE

LUTRA sp.

Text-fig. 7

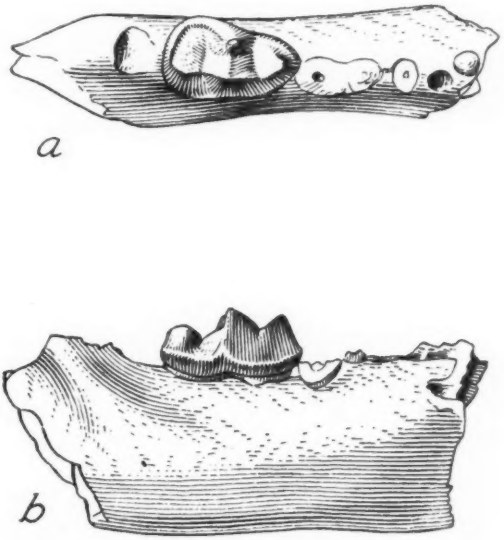
Localities and specimens.—V4844, Nightingale; UCMP 38704. V4945, Brady Pocket; UCMP 38694, 38795, 38695.

Several fragmentary lower jaws are referable to this genus. One of these (UCMP 38695) has an unworn carnassial, as well as the alveoli for the canine and the M_2, and the roots of the premolars. The configuration of the M_1 is nearly identical with that of the living European species *Lutra lutra* (Linnaeus) although the cingulum is more complete, the talonid somewhat broader, the hypoconid more prominent, the basin of the talonid flatter and, although the anterior edge of the paraconid rises at a slightly less abrupt angle, the cusps have the same relative position.

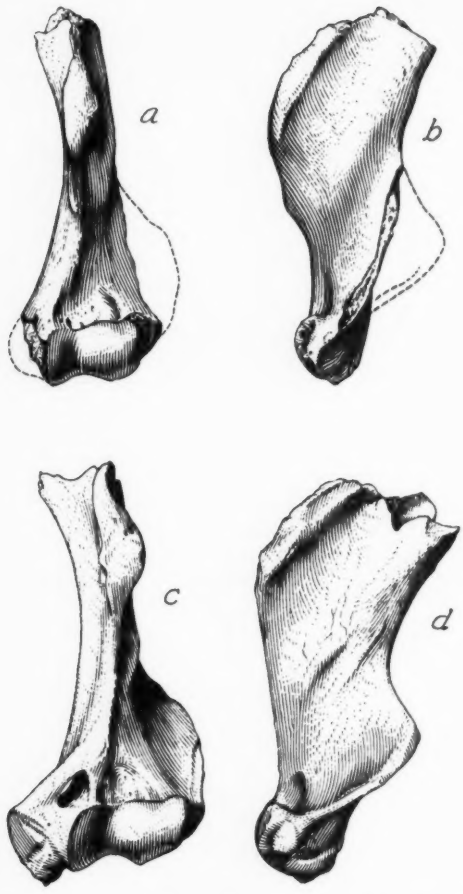
Lutra canadensis pacifica Rhoads differs from both the Nevada specimen and *L. lutra* in a stronger development of the cusps of the trigonid, the possession of a wider talonid with a widely expanded labial cingulum, a stronger development of the intra-protoconid-hypoconid cusp, an antero-posterior lengthening of the hypoconid, and an enlargement of the hypoconulid.

This form differs from *Lutravus halli* Furlong (1932) in the lesser height of the crown, the more posterior position of the hypoconid, and the more anterior position of the metaconid.

Discussion.—If this form is a true otter,



TEXT-FIG. 7—*Lutra* sp., right mandibular fragment UCMP 38695: *a*, occlusal view; *b*, labial view. ×1½.



TEXT-FIG. 8—?Mustelidae, gen. indet. Distal portions of two left humeri. *a*, *b*, UCMP 38703, anterior (or ventral) and external views. *c*, *d*, UCMP 33150, anterior and external views of mustelid from Niobrara River fauna. ×¾.

it would then follow that the European form is more primitive than the common American otters; at least insofar as the development of the M_1 is concerned, as the lower carnassial of the European species has changed little since early Pliocene times. The modern New World otters could have been derived from this form through a development of the talonid cusps and cinguli.

? MUSTELIDAE, gen. indet.
Text-fig. 8

Localities and specimens.—V4844, Nightingale; UCMP 38703. V4845, Brady Pocket; 38675.

The fragments of the distal ends of two humeri may be referred to this family. These strangely flattened and specialized bones have no close counterparts in any of the Recent carnivores observed by the author. There is a humerus (UCMP 33150) in the collections at Berkeley from the Barstovian Niobrara River fauna, which, although not identical, bears a striking resemblance to these fragments. The more complete specimen (UCMP 38703) has a wide trochlea, deeply rounded both anteriorly and posteriorly, with deep coronoid and olecranon fossi; the epicondylar crest is broken away (in the Niobrara River specimen it is widely flaring, forming a wide sulcus); the sulcus, partially shown in the Nevada specimens, is formed by the distal and posterior half of the spiral sulcus; it is divided by a longitudinal ridge; the crest of the greater tuberculum is not twisted but is oriented directly anteriorly, rising to a thin ridge from a laterally compressed shaft, and reaches an apex with a slightly widened deltoid tuberosity. The Niobrara River specimen has an epicondylar foramen, while there is an epicondylar foramen in only one of the Nevada specimens. The Nebraska form also has a more sharply defined and deeper coronoid fossa.

Discussion.—A comparison of these specimens with the humeri of recent burrowing and amphibious types of carnivores and rodents indicates that this animal had an extreme aquatic adaptation. *Taxidea* has the same general sort of adaptation but the detail of design in its humerus is quite different. Among the semi-aquatic mammals there is a more detailed similarity in the adaptation of this bone.

The relationship of this Nevada mustelid to other carnivores with aquatic adaptations cannot be established. A possible relationship might exist between it and *Semantor* from the early Pliocene of Siberia but, unfortunately, this genus is known only from the posterior half of a single skeleton.

FELIDAE, gen. indet.

Locality and specimens.—V4845, Brady Pocket; UCMP 38696, 38791.

Several bones from the pes of a large

cat were found at this locality. These included the right metatarsals II and III, an astragalus, and a calcaneum. These bones are slightly smaller and stouter than their counterparts in the modern *Felis concolor californicus* May and slightly more than two-thirds the size of the nearly contemporaneous *Pseudaelurus pedionomus* Macdonald (1947) from the Minnechaduza fauna of Nebraska. This cat may be related to either *Felis*, *Pseudaelurus*, or *Panthera*.

Order PROBOSCIDEA
MAMMUTIDAE or GOMPHOTHERIIDAE, gen. indet.

Locality and specimens.—V4844, Nightingale; UCMP 38706, 38707.

Remains of proboscideans are surprisingly rare in the Nightingale Road area in contrast to their relative abundance in other Nevada Pliocene faunas. A badly shattered cheek tooth (UCMP 38707) and a deciduous premolar (UCMP 38706) are the only remains of this order recovered from these localities.

Order PERISSODACTYLA
TAPIRIDAE, gen. indet.
Text-fig. 9

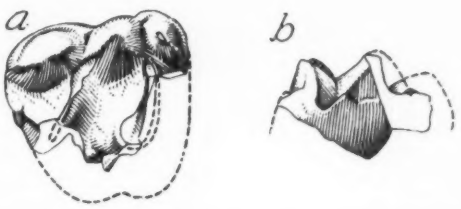
Locality and specimen.—V4845, Brady Pocket; UCMP 38818.

A fragment of right upper cheek tooth is the only record of this family in the far western lower Pliocene deposits. The ectoloph has three sharply separated cusps; a prominent parastyle, equaling about half the size of the paracone; the paracone and metacone are subequal; there is a well developed cingulum around the metacone that may have extended on around the paracone; the metaloph and protoloph are strongly connected with the metacone and paracone, respectively; the tooth is brachyodont and measures 24.0 mm. from parastyle to metacone.

Family EQUIDAE
NEOHIPPARION cf. N. OCCIDENTALE
Text-fig. 10

Locality and specimens.—V4845, Brady Pocket; UCMP 38693, 38799, 39323, 39327, 39328.

A series of isolated cheek teeth from the Brady Pocket are tentatively referred to this



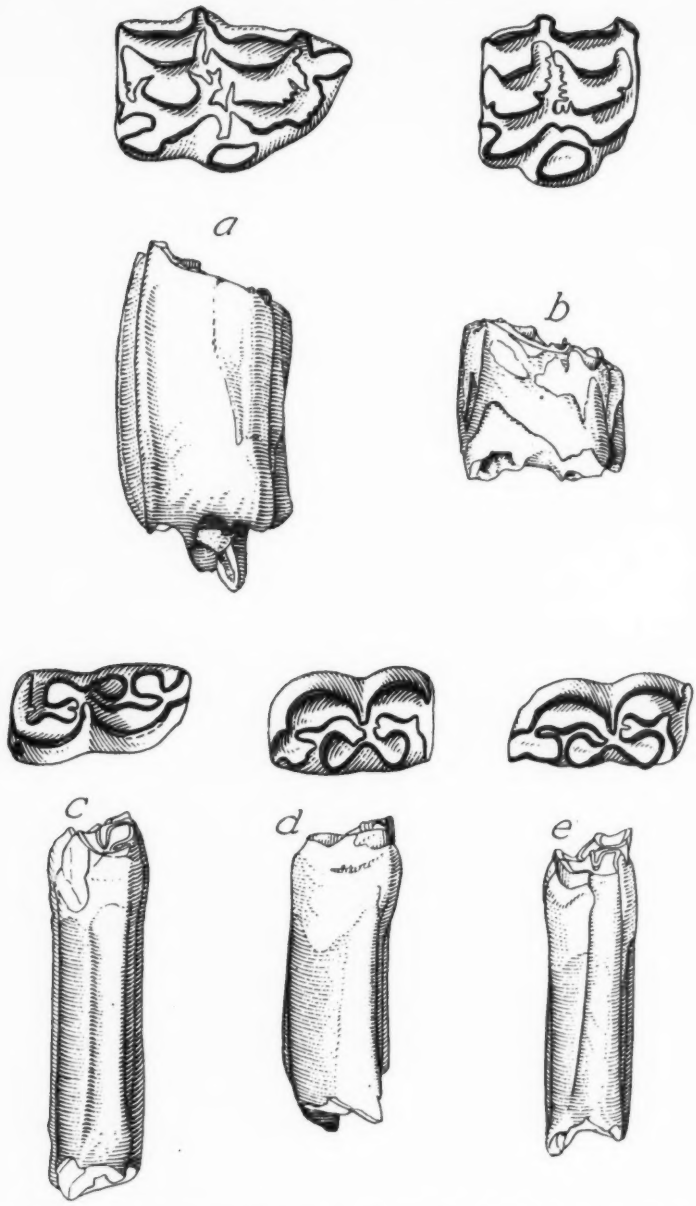
TEXT-FIG. 9—Tapiridae, gen. indet. Fragment of right upper cheek tooth UCMP 38818: *a*, occlusal view; *b*, posterior view. ×1.

species. These include upper teeth with extremely complicated fossette borders which, however, do not exceed in complexity those in the type of *N. occidentale* (Leidy). Two of the M^2's are heavily worn so that only 12 mm. of the crown remains, and these have rounded protocones. The lower cheek teeth are highly variable; in the molars the inflection between the protoconid and the hypoconid swings lingually until it nearly touches the inflection between the metaconid and the metastylid. This feature also is found in the Chalk Spring *Neohipparion* and in a first lower molar from Big Spring Canyon. One tooth has two small plicaballinids and two have very small irregularities which resemble incipient plicaballinids. An M_3, which is worn to within 15 mm. of the base, has an isolated parastylid; and an M_1 has the parastylid divided into isolated lakes, one extending to within 14 mm. of the base and the other to within 20 mm. of the base. It may also be noted that a single isolation of the parastylid is found in two of the M_1's from Big Spring Canyon.

Discussion.—Isolated teeth of this type are of little value in close correlation, as similar forms are found in the middle Clarendonian Fish Lake Valley fauna as well as in the late Clarendonian Chalk Spring fauna. The species *Neopipparian occidentale* (Leidy) either has a wide range through time in Western America or there were several contemporaneous or temporal subspecies that formed a very closely knit group which canot be separated by characteristics displayed in isolated teeth.

NEOHIPPARION sp.
Text-fig. 11

Locality and specimen.—V4845, Brady Pocket; UCMP 38659.



TEXT-FIG. *10*—*Neohipparion* cf. *N. occidentale*. *a*, P^2, UCMP 39328; *b*, upper cheek tooth, UCMP 39327; *c*, lower cheek tooth, UCMP 39323; *d*, lower cheek tooth, UCMP 38693; *e*, lower cheek tooth, UCMP 38799. Occlusal and posterior views. ×1.

One of the first two specimens obtained from this fauna was a *Neohipparion* upper molar which was presented to the author by Mr. R. E. Bradŷ of Brady's Hot Springs, Nevada. This practically unworn M^2 (UCMP 38659) has a crown pattern which closely resembles that of an M^2 (UCMP 33405) from Big Spring Canyon, but differs slightly in having the fossette more widely open and the protocone

located somewhat more lingually than in the South Dakota specimen. The curvature of the two teeth is alike. The Big Spring Canyon specimen is slightly higher crowned with a groove in the parastyle which does not extend quite so far up the corner of the tooth. The Nightingale Road tooth is pinched in at the base, and the parastyle and metastyle are broadly expanded and nearly touch at the base.

Discussion.—Gregory (1942) included the Big Spring Canyon tooth with his other specimens which he referred to *Neohipparion occidentale* (Leidy). A further study of this specimen and the Brady Pocket specimen suggests that these teeth may represent a different species. The extreme flattening of the protocone and its great anteroposterior length seem to indicate a relationship to *N. sinclairi* (Wortman) from the middle Pliocene. The protocones retain this flattening and lengthening to the base of the tooth. It should be noted that in neither of these teeth are the anterior borders of the prefossettes plicated, as is common in many of the other specimens of neohipparions from faunas of this age.

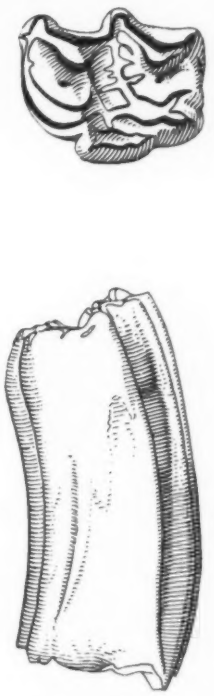
EQUIDAE, gen. indet.

The collection contains numerous complete and fragmentary phalanges, podials, and metapodials of horses. These are all the size of those in *Neohipparion occidentale* (Leidy). It should be noted that the position of the central prominence for the fetlock collateral ligament of the metapodials indicates that the side toes were tightly appressed to the cannon bone, and the central prominence is in an anterior position as it is in most neohipparions.

Discussion.—There is always the possibility that some of these bones may belong to a species of *Hipparion*, but there are no teeth that may be assigned to this genus in the fauna. The tightly appressed splints eliminate the possibility that any of these cannon bones belong to a small species of *Pliohippus.*

Order ARTIODACTYLA
Family MERYCOIDODONTIDAE
USTATOCHERUS sp.
Text-fig. 12

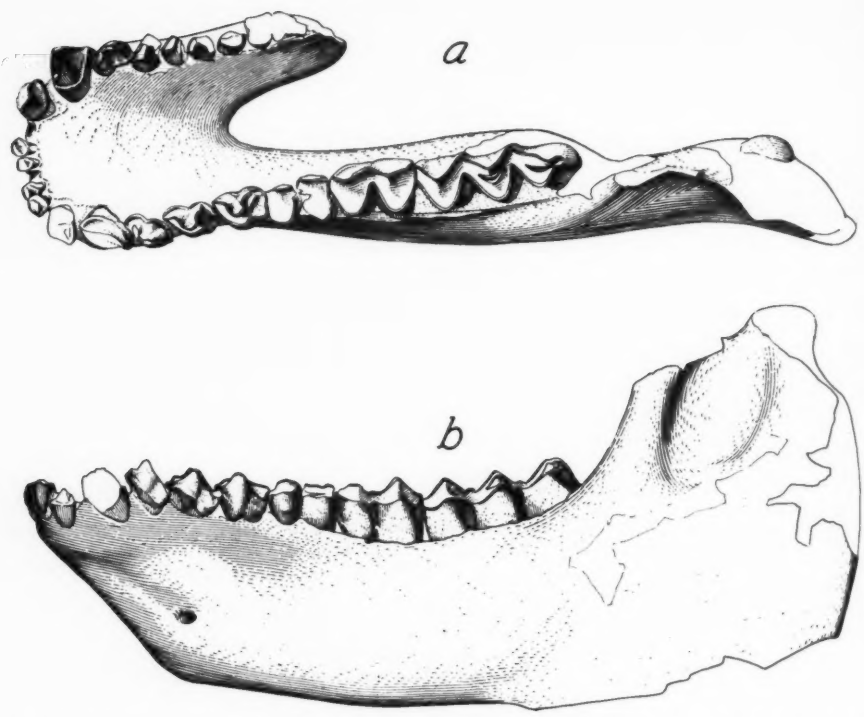
Locality and specimen.—V4845, Brady Pocket; UCMP 38821.



TEXT-FIG. *11*—*Neohipparion* sp. M^3, UCMP 38659, occlusal and posterior view. ×1.

The oreodonts are represented in this fauna by a single lower jaw. The teeth are brachyhypsodont. M_3 has deep labial notches between the crests, large lingual styles between the crescents, the third crescenta and the third crescent are large. M_2 is simple and without styles. M_1 is also without styles and has subequal crescents. P_4 has a well developed lingual valley opposite the principal cusp. P_3 has a similar valley and an anterior ridge with a median lingual cusp. P_2 is oriented obliquely and has a large central cusp and a smaller anterior cusp. P_1 is also obliquely oriented and is caniniform. All of the premolars have prominent basal cinguli on the lingual side. The canine is about the same size and shape as P_2 but without accessory ridges or cusps and has a prominent lingual cingulum. The incisors become progressively smaller and all have a well developed posterior basal cingulum.

Discussion.—This specimen shows the characteristics which typify *Ustatochoerus* Schultz & Falkenbach (1941). A specific



TEXT-FIG. *12*—*Ustatochoerus* sp. Incomplete mandible, UCMP 38821: *a*, occlusal view; *b*, labial view. ×0.4.

determination cannot be made from this jaw without an associated cranium.

Genus AEPYCAMELUS,[1] new name

While describing a partial skeleton of a large camel with giraffe-like proportions from northeastern Colorado, Matthew (1901) proposed the name *Alticamelus* and designated *Procamelus altus* Marsh as the type species of the genus. In line with common practice he referred the Colorado

[1] Tall, towering; camel.

COMPARATIVE MEASUREMENTS (MM.) OF *Ustatochoerus*

	Brady Pocket specimen	*U. profectus**	*U. californicus† raki*	*U. compressidens†*	*U. major†*	*U. medius†*
M_3, A-P diam.	49.6	41.0				
M_2, A-P diam.	29.5	23.0				
M_1, A-P diam.	22.3	18.0				
P_4, A-P diam.	18.7					
P_3, A-P diam.	19.2	17.4				
P_2, A-P diam.	17.5	15.5				
P_1, A-P diam.	18.1	12.0				
Depth of ramus under anterior end of M_3	55.9			46.5	51.0	43.0
Length of P_1–M_3	162.0		169.0	135.0	149.0	115.0
Length of M_1–M_3	100.4	82.0	105.0	85.0	92.0	71.0

* After Matthew & Cook (1909).
† After Schultz & Falkenbach (1941).

specimen to this species. Unbeknownst to Matthew, the type of *P. altus* was a single isolated calcaneum. Matthew stated

> Professor Marsh in 1894 described and figured a camel calcaneum which agrees in size with that of the giraffe-camel (among others) and states that other portions of the skeleton show that it exceeded in size any other described from this country and that the extremities were especially elongated.

Further investigation revealed that Marsh's type was actually only the single calcaneum. Consequently, Matthew (Matthew & Cook, 1909, p. 402) stated that this type of *P. altus* was indeterminate and named the Colorado specimen *Alticamelus giraffinus*, considering it a neotype for the genus, "although not its type species." This step clearly indicated the concept that Matthew had of the genus *Alticamelus*, although it did create a taxonomic problem. At best, the calcaneum from the Rattlesnake of Oregon, which bears the name *Procamelus altus* Marsh is a *nomen vanum* and in all likelihood is really the calcaneum of a species of *Paracamelus*. In order to alleviate this situation, I propose that the name *Aepycamelus* be substituted for *Alticamelus* and that *A. giraffinus* (Matthew) be the type species.

The following species may be recognized as members of this genus:

A. giraffinus (Matthew), 1909
A. procerus (Matthew & Cook), 1909
A. priscus (Matthew & Cook), 1909
A. leptocolon (Matthew), 1924

Stirton (1929), in discussing the artiodactyls of the Fish Lake Valley beds, listed the cranial characteristics which can be used to distinguish between *Alticamelus* and *Procamelus*. As a basis for this diagnosis he used the type of *Alticamelus alexandrae* Davidson, 1923, for his standard for *Alticamelus*. As the result of more recent discoveries, this species has been placed in the genus *Hesperocamelus* Macdonald (1949), thereby, unfortunately, invalidating this diagnosis. With the material now available, *Aepycamelus* may be distinguished from *Procamelus* on the basis of its great size and elongated limbs; the dentition is very close to that of *Procamelus*.

AEPYCAMELUS BRADYI, n. sp.
Text-fig. 13

Type.—Cranium, UCMP 38668. Nearly perfect cranium with complete upper dentition.

Type locality.—UCMP V4845, Brady Pocket.

Fauna.—Nightingale Road.

Age.—Early Pliocene, Clarendonian.

Diagnosis.—Larger than other known species; total length of cheek tooth row one-forth larger than *A. giraffinus* (Matthew); length of premolar series equal to *A. giraffinus*, molar series much longer.

Description.—Cranium long, narrow and massive, slightly longer than in *Camelus* with narrower palate and cheek tooth series nearly parallel, muzzle with same proportions as *Camelus*. Rostrum restricted behind

Comparative measurement (mm.) of *Aepycamelus*

	A. giraffinus	*A. procerus*	*A. bradyi*	
Condylobasal length	425.0	—	512.0	512.0
Basal length	410.0	—	—	490.0
Palatal length (approx.)	245.0	—	—	310.0*
Postglenoid length	354.0	—	—	—
Dental measurements at alveolar border				
Length C–M^3	200.0	—	258.3	251.7
Length P^2–M^3	135.5	158.0	160.8	165.0
Length M^1–M^3	88.0	98.0	108.5	113.2*
Canine, A-P diam.	20.0	—	15.7	15.6
Canine, Tr. diam.	11.9	—	11.5	10.1
Diastema behind canine	18.8	25.0	29.6	29.6
P^1, A-P diam.	16.1	—	15.0	13.4
P^1, Tr. diam.	12.7	—	10.5	10.0
Diastema behind P^1	30.0	23.0	42.3	38.1
P^2, A-P diam.	13.1	18.0	12.5	11.8
P^2, Tr. diam.	7.7	9.5	6.8	5.8
P^3, A-P diam.	15.0	20.0	15.2	17.3
P^3, Tr. diam.	10.0	12.0	10.8	11.4
P^4, A-P diam.	16.1	20.0	19.6	21.0
P^4, Tr. diam.	15.1	19.0	17.8	18.2
M^1, A-P diam.	26.2	23.0	broken	28.4
M^1, Tr. diam.	23.9	22.0	broken	29.1
M^2, A-P diam.	31.3	33.0	36.7	35.6
M^2, Tr. diam.	28.8	38.5	27.0	25.9
M^3, A-P diam.	31.2	34.0	42.2	41.3
M^3, Tr. diam.	24.0	27.0	23.2	23.8

* Approximate.

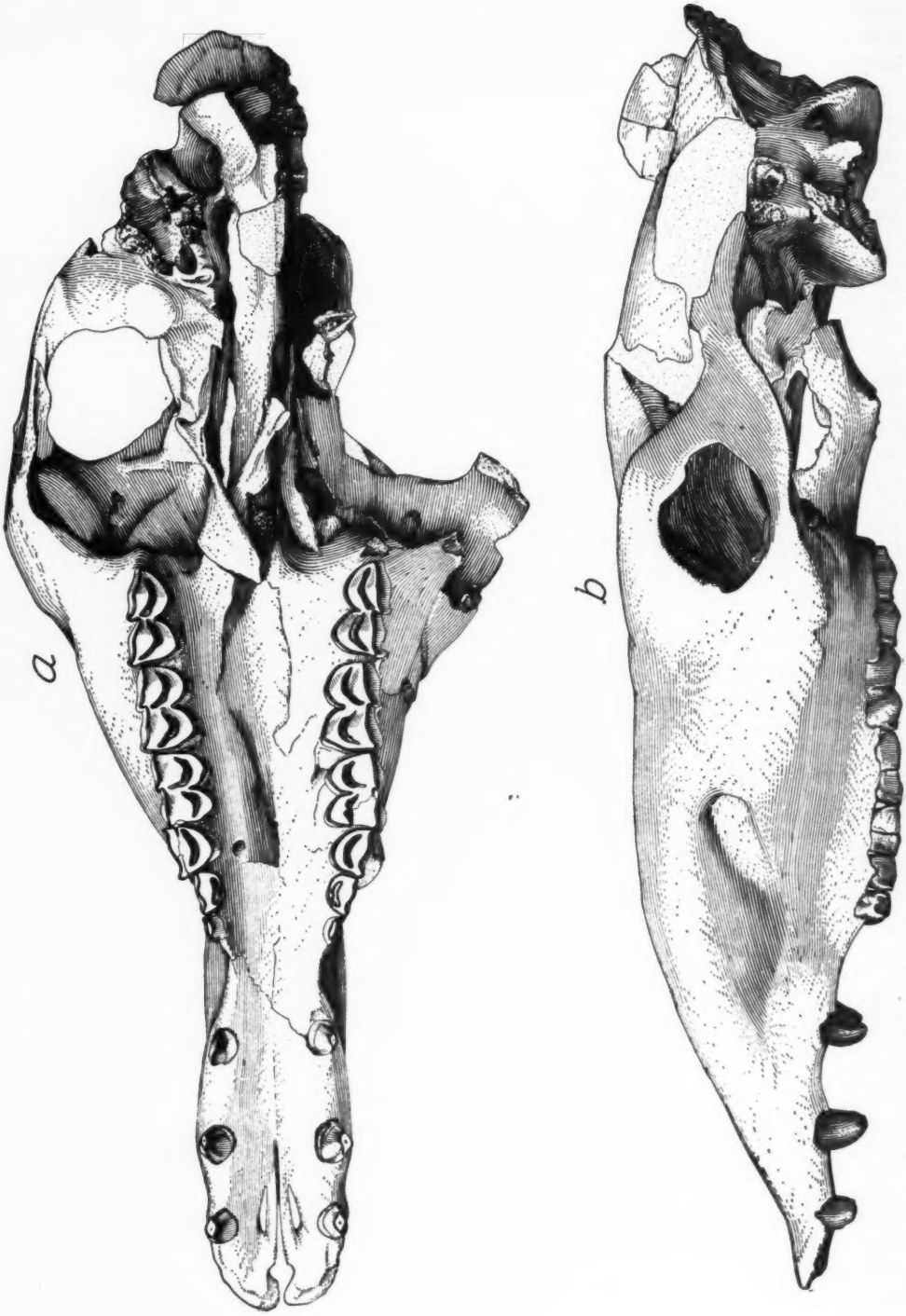


PLATE VIII.—*Aetoxomelus bradyi*, n. sp. Holotype, cranium, UCMP 38608: *a*, occlusal view; *b*, view of left side. X ½.

FIGURE 11. *Aepycamelus bradyi*, n. sp. Holotype, cranium, UCMP 38668; *a*, occlusal view; *b*, view of left side. X ¼.

P^1. Brain small; sagittal and lambdoidal crests strongly developed; zygoma strong and rising nearly to center of orbit; tips of premaxillaries rounded and nearly joined anteriorly forming a foramen that extends posteriorly to a point opposite proximal end of incisive foramen, anterior tips slightly upturned; large deep facial fossa connects with pocket above the infraorbital foramen; rostrum widest between canines as in *Camelus*.

Upper teeth.—I^3, canine, and P^1 massive and slightly recurved with trenchant anterior and posterior borders. P^2 not greatly reduced, similar to *Hesperocamelus* and the Burge *Procamelus*, no internal crescent in contrast to *Hesperocamelus*. P^3 elongate with internal crescent nearly complete except for small break in anterior moiety. P^4 as in *Procamelus*. M^1 one-third longer than wide in contrast to square M^1 of *Procamelus* in middle stages of wear. M^2 and M^3 progressively longer antero-posteriorly than in *A. giraffinus* (Matthew). P^{3-4} with well developed anterior and posterior styles. M^{1-2} with poorly developed mesostyles; anterior style not developed on M^1, weakly developed on M^2; metastyle undeveloped on M^3. Ribs well developed on all cheek teeth.

Discussion.—This species is referred to *Aepycamelus* on the basis of size and the progressive development of the molar series over that of *A. giraffinus* (Matthew). It further demonstrates the dental parallelism between *Aepycamelus* and *Procamelus* and the similarity of these forms to the more primitive *Hesperocamelus*.

CAMELIDAE, gen. indet.

The camels are by far the most common element in this assemblage. A dozen complete astragali were collected and at least twice as many fragmentary ones were cast aside. In addition, numerous phalangial, podial, and metapodial fragments were found.

Astragali of three distinct size groups, with a possible fourth group represented by one bone, were collected. The larger specimens may belong to *Aepycamelus bradyi* Macdonald. These are slightly larger than those of *A. procerus* (Matthew & Cook) from the lower Snake Creek fauna and about equal to those of a small *Paracamelus* from the Hemphill fauna. The smaller groups fall within the range of the *Procamelus* and *Pliauchenia* specimens from the Big Spring Canyon fauna. The smallest one is similar to the astragali of *Hesperocamelus stylodon* Macdonald from the Chalk Spring fauna of Elko County, Nevada.

There are several large proximal phalanges that are slightly larger than those belonging to *A. procerus* (Matthew & Cook). These may belong to *A. bradyi* Macdonald.

CONCLUSIONS

With the exception of the two Nightingale Road localities, there are only fragmentary mammalian remains known from the Truckee formation. The sites at Verdi, Hazen, and Kawsoh have not produced any material that may be used for close correlation. The Nightingale and Brady Pocket collections now give us a basis for the correlation of at least part of the Truckee formation.

Two forms from this fauna, *Eucastor* near *E. lecontei* and *Osteoborus diabloensis* Richey indicate a correlation with the late Clarendonian Black Hawk Ranch fauna of California; the beaver is also found in the Chalk Spring fauna in northeastern Nevada.

The presence of *Pseudaplodon occidentale* n. sp., is of particular interest as it once again points to the peculiar provinciality of the aplodontids. All of the members of this family, with the exception of the single Asiatic species, *P. asiaticus* Schlosser, from the middle Pliocene Ertemte beds, are found in western North America.

The scarcity of proboscideans in this fauna and the contemporaneous Chalk Spring fauna was unexpected in the light of their relative abundance in earlier and later faunas in the Great Basin. As in other Pliocene faunas, the camels held a dominant position and their remains are the most abundantly represented.

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NOTES ON HALYSITID CORALS

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ABSTRACT—A few records are added to published summaries of halysitid species. Hall's name *H. gracilis* must be dropped, and part of the material which has been so-called is defined as *Catenipora rubra*, n. sp., Ord., Manitoba.

A RECENT taxonomic study of the coral family Halysitidae (Buehler, 1955) adds to our knowledge of the group, but leaves many questions unanswered and many problems unsolved. Solution of these problems must await detailed work, but some immediate comments may be useful. We therefore offer these brief notes, based on Buehler's work.

I. *Catenipora gracilis*

Buehler (p. 36–38) has suggested that the name *Catenipora gracilis* Hall be used, in the sense of Lambe, and with a neotype selected from material described by Leith. The history of this name is:

1843. Castelnau (p. 45, pl. 17, fig. 3) described and figured a specimen from the "Iles situées dans la partie septentrionale du lac Huron" as *Catenipora escharoides* [Lamarck].

1849. Milne Edwards (pl. 65 *bis*, fig. 2, 2a) figured *Catenipora gracilis* Milne Edwards et Haime [new species] from "l'île de Drummond au lac Huron," stating that this was the species described by Castelnau as *C. escharoides*.

1851. Milne-Edwards and Haime (p. 281–284) placed their *Catenipora gracilis* in synonymy with *Halysites catenularia* [Linné], and placed Castelnau's *C. escharoides* in synonymy with *H. escharoides*. (We mention this action, since Buehler considered that it justified him in ignoring the name, but see below under Hall, 1862.)

1851. Hall (in Foster & Whitney, p. 212, pl. XXIX, fig. 1a, 1b) described and figured *Catenipora gracilis*, n. sp., from green shales near the upper part of the Hudson River group, on the eastern shore of Green Bay, Wisconsin.

1862. Hall (in Hall & Whitney, p. 430) placed his *Catenipora gracilis* in synomymy with *Halysites catenularia* (Linné sp.).

1900. Lambe (p. 68–70, 74–75, pl. III, fig. 5–7) described *Halysites catenularia* var. *gracilis* Hall from six localites; two in the region of Lake Winnipeg, three from the Hudson Bay slope of northern Manitoba and Ontario, and one from Anticosti. The age of all these specimens was given as Galena-Trenton, except that from Antocosti which was said to be from the Hudson River. Lambe's figured specimens were from East Selkirk, Manitoba; Jack Head Island, some 120 miles north in Lake Winnipeg; and from Churchill Harbour on Hudson Bay.

1935. Kay (p. 577, etc.) listed *Halysites gracilis* (Hall) from the Stewartville of Iowa and adjacent regions, and at the same time pointed out the strong resemblance of the associated fauna to that of the Red River beds of Manitoba.

1944. Leith (p. 268–270, pl. 42–43) described and figured *Halysites gracilis* (Hall) from the Selkirk member of the Red River formation of Manitoba.

In the light of this history, let us return to Buehler's suggestions. Milne Edwards' *Catenipora gracilis* was adequately figured in a widely distributed book, the type locality and distinguishing characters were stated in the explanation of the plate, and reference was made to a previously published description. We see no justification for suppression of this name. That Milne-Edwards and Haime later considered (herein agreeing with all their contemporaries) that *Halysites catenularia* was a very broad inclusive species is surely irrelevant. Whether the species can be recognized is a matter for judgement of coral experts, but the name is valid whether it can be applied to material other than the types or not. Much of the Stokes collection is in the British Museum, and quite possibly the

specimen figured by Milne-Edwards is also preserved there. (Since Buehler gives only one reference to Milne Edwards and Haime under the date 1849, one would assume that it was the source of this 1849 species. That is not so, and no species of *Halysites* are described in the paper he cites.)

Buehler could not locate the type of Hall's *Catenipora gracilis*, nor any topotype material, and suggested that Hall's specimen may have been derived from the drift, or that Hall was mistaken in his locality. These possibilities seem to us very doubtful. It is clear from Hall's account that he personally studied the section at Green Bay, and in the Wisconsin report of 1862 he emphasized the stratigraphic position of his specimen, pointing out that a specimen which had later been found in the Galena was not only older but to some extent morphologically different from his species.

Certainly, the species must be rare. Jones (1931) does not list any *Halysites* in the material she collected from the Upper Ordovican of Wisconsin, and Ladd (1929) did not find it in Maquoketa beds in Iowa which are generally considered contemporaneous with the green shales exposed on Green Bay. However, a *Halysites* has been figured, without description, from the Big Hill member of the Richmond in the northern peninsula of Michigan (Hussey, 1926, pl. XI, fig. 14), within 50 miles of the presumed locality of Hall's species. The species, now nameless, must rest on Hall's description and figures until new material from the Richmond of Green Bay can be found and studied.

As we have suggested, Lambe's material was derived from widely separated localities, with no assurance of contemporaneity, so that we cannot speak of *Halysites gracilis* sensu Lambe in any meaningful way. His specimens seem to have varied considerably among themselves, judging from his summary of their characters and dimensions.

We can, however, speak intelligibly of *Halysites gracilis* sensu Leith, for we have good photographic illustrations of extant material. At first glance the simple course would seem to be follow Buehler in treating Leith's material as typifying the species, and to replace the homonymous name *gracilis*. We shall name a Manitoba species, but it must be emphasized that this is a new species, and not a new name for Hall's species. Buehler has stated that Leith's material is of the same age as Hall's, but this is a circularity, since the mutual occurrence of *Halysites gracilis* in the Richmond and in the Red River was one of the few remaining props for the theory that the Manitoba beds were of Richmond age. Kay has shown that the Red River fauna is strikingly similar to that of the Stewartville. Flower (1952, p. 26, etc.) has shown that the "characteristic" Red River cephalopod genera occur in the upper Trenton of Quebec. The suggestion that a Red River coral "should" be the same as one from beds of Richmond age seems unwarranted by the facts. We know that halysitids occur in the Stewartville of Iowa and Wisconsin (Kay, Hall) and in the "Middle Black River in the Upper Mississippi valley" (Foerste, 1924, p. 21). It is regrettable that Buehler did not mention these records, nor describe the forms they refer to. One may more plausibly suggest that the Red River species is the same as a Trenton one, rather than a Richmond form, but in the absence of detailed knowledge of either, any such suggestion is groundless.

We now have three named species of halysitids from the Ordovician of the Arctic, and three more from British Columbia, but the form (or forms) occurring on the rest of the continent are nameless, apart from the Black River *Catenipora quebecensis*. In order that there may be some datum to which the Trenton and Richmond forms may be referred when they are studied, we now propose **Catenipora rubra** Sinclair and Bolton, new species, having as synonym *Halysites gracilis* of Leith, 1944, e.p., i.e. the form illustrated by his figures 5 and 6 on plate 43 (not *Catenipora gracilis* of Milne Edwards, nor of Hall, nor of Buehler, nor of authors), and having as holotype the specimen numbered 109 in the University of Manitoba collections, figured by Leith.

Further description of this species will be given shortly, along with description of the species described by Leith under the same name, and figured in pl. 43, fig. 4. This latter species (in which the ranks are often double and sometimes favositid) is an entirely distinct form, allied to *Tetradium*.

II. DRUMMOND ISLAND HALYSITIDS

Again we must leave to others with access to material the task of untangling the synonymies, only pointing out here that, if the Ordovician forms suffer from a lack of specific names, those from the Gotlandian of Drummond Island have a surfeit. This locality has produced the types of four species: *Catenipora labyrinthica* Goldfuss, 1826, *C. michelini* Castelnau, 1843, *C. gracilis* Milne Edwards, 1849, *Halysites huronensis* Teichert, 1937. The types of the Goldfuss and Teichert species were in Bonn in 1937 (Teichert 1937, p. 135–136). We do not know if those of the other species are available, but they should be sought before the names are discarded. It has been assumed that these species are all from Gotlandian strata. Beds of Upper Ordovician age occur on Drummond Island, but no halysitids seem to have been reported from them (see Hussey 1952, p. 49, seq.).

III. *Catenipora parrii*

Buehler, in his Catalogue of Species (p. 27–28) lists four forms with the notation that he was unable to find descriptions of them, and that possibly they were nomina nuda. We give references to these, as well as to two other forms which Buehler does not mention.

Catenipora parrii was the first halysitid species to be described from America, and as such should be the proper name for one of the Arctic Gotlandian forms. We cannot settle the position of this species, but summarize here what is known of it. The reference (which is in Bassler's Index of Ordovician and Silurian Fossils) is, in full:

A / Supplement / to / the Appendix of Captain Parry's voyage for the / discovery of a North-West Passage, / in the years 1819–20. / Containing / an account of the subjects / of / Natural History. / London: John Murray, Albemarle Street / MDCCCXXIV.

It is paged clxxxiii-cccx, with pl. 1–2 and [A-D]. The section "Rock Specimens," by Charles Konig, Esq., F.R.S., &c., occupies pages ccxlvii-cclvii, and is not illustrated. Konig wrote (p. ccl-ccli):

> Another species of a genus of zoophytes, peculiar to the transition limestone, was found by Captain Parry, in Prince Regent's Inlet, at the foot of a high hill. It is a fine Catenipora, which appears to be quite distinct from the common chain coral of Gothland, and other countries. Lamarck has two species of this genus, namely, the common one, which is (rather unaptly) called by him *C. escharoides;* and another, which he distinguishes by the name of *C. axillaris*, though it appears from his reference to a figure in the Amœnitates Academicæ, that he is speaking of TUBIPORA *serpens, L.*, which is not a congener of, and can indeed scarcely be considered as belonging to, the same natural order with Catenipora. We may, therefore, look upon this arctic species as an undescribed and anonymous one. I call it CATENIPORA *Parrii:* tubulis crassiusculis, compressis, collectis in laminas sinuatas varie sese coalites, tubulorum orificiis ovatis sæpe confluentibus: dissepimentis confertissimis.
>
> The space between the laminæ is filled up by a yellowish calcareous mass; the tubes themselves are converted into carbonate of lime, internally drused with minute crystals of the same substance.

This specimen was collected from the Gotlandian on the west side of Brodeur Peninsula, Baffin Island. The description is, by modern standards, meagre, but the name can scarcely be considered a nomen nudum, as was done by Lee. This author (Lee, 1912, p. 257–258, fig. 8) described as *Halysites labyrinthica* (Goldfuss) a specimen which he suggested might possibly be Konig's type of *C. parrii*. This seems improbable from the published records, for the material examined by Lee was in the collection brought back by Parry's third expedition, which had been referred to Jameson for report. The specimen is in the Royal Scottish Museum, and presumably is what Jameson referred to when he wrote (1826, p. 146): "organic remains observed in the limestones [from Port Bowen] are entrochites, catinulariæ. . . ." The collections from Parry's first expedition were submitted to Konig when he was at the British Museum, and presumably were kept there.

IV. *Catenipora compressa*

This species was described and figured by Milne-Edwards (1849, pl. 65 bis, fig. 3) as *Catenipora compressa* Milne-Edwards et Haime, the figured specimen coming from Dudley. In 1851 Milne-Edwards and Haime placed it, like *C. gracilis*, in synonymy with *Halysites catenularia*, giving at the same time a reference to the original description.

V. *Halysites undulata*

This seems to be one of the species included by Kiær in his monographic study of the corals of the Oslo region, of which only parts have been published. This form, as *Halysites undulata* or *H. escharoides* var. *undulata*, was listed (Kiær, 1897, p. 10, 50, 71) from the Gastropod limestone (5a) of Ringerike, Norway, and from the Lyckholm and Borkholm of Esthonia, but it has not been described, so far as we know.

VI. *Halysites wallichi*

This species was described by Reed (1912, p. 129–130, pl. XVIII, fig. 8–10) from the Gotlandian of Spiti, where it occurs with the new variety *Halysites catenularia* Linn. var. *kanaurensis* Reed (op. cit., p. 128–129, pl. XVIII, fig. 4–7) which was not mentioned by Buehler. These descriptions are readily accessible, and there is no need to repeat them here.

VII. *Halysites parvitubus*

This species was described by Lindström (1880, p. 33, pl. I, fig. 10) from Boda, Sweden.

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PALEONTOLOGICAL NOTES

DINOSAUR EXTINCTION: ONE MORE HYPOTHESIS

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ABSTRACT—Attention is called to the great destruction that resulted from a meteorite impact in Siberia in 1908. A larger impact would cause more widespread destruction. Several larger impacts may have occurred in geologic time. The survivals and extinctions at the close of the Cretaceous are such as might be expected to result from intensely hot winds such as would be generated by extra large meteoritic or planetesimal impacts. It is suggested that, when the various hypotheses as to dinosaur extinction are being considered, this one be added to the others.

MANY large and previously flourishing animals became extinct at the close of the Cretaceous. The date of their passing may have been a matter of thousands of years, but no fossil evidence clearly proves this idea; the time might have been much more brief. No proof exists as to what caused these extinctions; we have only the opinions or guesses of various paleontologists. Several bits of evidence do exist, however, and may be reconsidered. These clues point toward one explanation which has seldom been noticed and never emphasized, but which deserves notice along with the others.

The literature on plant fossils indicates that a drastic change in the world's vegetation occurred between the Jurassic and the Cretaceous, but not at the Laramide Revolution (the end of the Mesozoic). Angiosperms were certainly extremely rare before the Cretaceous, but during that period they increased with explosive rapidity, and assumed the dominant position in the world's landscape that they now occupy. The Raritan (Cretaceous) formation of New Jersey contains over 200 species of fossil Angiosperms, about 70 percent of all the plant species that occur there. In the succeeding Magothy flora (still Cretaceous) the modern type plants are equally dominant with (for example) oaks, sassafras, tulip trees, sedges, and grasses.

The Cretaceous grasses warrant emphasis. These plants, seemingly humble, are the world's best fodder for large animals. In zoos, the large mammals are appropriately called the "hay stock." The great herds of American bison lived in grassland. The huge African animals, such as zebra, rhinoceros and eland, are inhabitants of the grassy plains or veldt; grass is their necessary nourishment.

The Dakota flora, also of Cretaceous antiquity, is very interesting, comprising several hundred species, 90 percent of which are flowering plants. This quite modern-type vegetation occurred through Minnesota, Iowa, Nebraska and Kansas, where bison recently flourished, and where the large Cretaceous animals similarly flourished.

There is no evidence of a radical change in the world's vegetation at the time of or since the Laramide Revolution. The Eocene reveals plant life continuing in much the same pattern as before the "revolution." The animals that prospered on that vegetation for millions of years in the Cretaceous should have continued into the Tertiary, but many did not. Which ones did not? Why did some survive?

There is no evidence of a radical change in the under-water life of the earth coincident with the Laramide Revolution, although many large cephalopods died out. This is to say that the completely aquatic faunas of the Paleocene do not differ markedly from those of the late Cretaceous. Thus a study of the fossils of most invertebrate and fish groups does not offer clues as to the nature of the post-Cretaceous reptilian catastrophe.

Non-aquatic invertebrates are, and long have been, chiefly hexapod in nature. The paleontologic record of insects is too irregular, too often broken, to help with the present problem. Non-aquatic vertebrates, however, do afford some extremely interesting data.

Reptilian life reached a climax in the

Cretaceous. These animals were more numerous and larger than ever before, immensely more numerous and individually large than since. Almost certainly the increasingly nourishing plant life contributed to this waxing in length, girth and abundance. Seven or eight orders of Reptilia existed in the late Cretaceous.

The Chelonia had been present since at least the Triassic, about as common as they are today.

The Sauropterygia were represented in the Cretaceous only by the plesiosaurs, which had turtle-like bodies and long snake-like necks. Their obvious ancestry goes back to the Triassic. The Ichthyosauria were even more beautifully adapted to fish-catching, but they appear to have become extinct early in the Cretaceous. Large plesiosaurs may also have vanished prior to late Cretaceous, although this is not certain.

The Rhynchocephalia must have existed through the Cretaceous because one species (*Sphenodon*) still lives in New Zealand. This primitive type goes back at least to the Triassic, and is represented by at least one species in the Jurassic, but by no Cretaceous or Tertiary fossils. It is much like the earliest (Carboniferous) reptiles.

The Crocodilia, new in the Jurassic, continued through the Cretaceous, survived its close, and have become more common in the Cenozoic.

The Pterosauria, new in the Jurassic, flourished through that period and until the end of the Cretaceous, when they became extinct.

If one regards the Dinosauria as a single order, there were seven reptilian orders in the Cretaceous, but there were eight if one separates the Dinosauria, as is probably better, into two orders. The Saurischia appeared in the Triassic, and were large and numerous through the Jurassic, reaching a climax of size and abundance late in the Cretaceous. The Ornithischia did not certainly evolve until the Jurassic, but were extremely common and big animals until the Laramide Revolution.

The Squamata, new in the Jurassic, became more common in the Cretaceous, and have increased further in the Cenozoic. In the late Cretaceous we find common large aquatic lizards called mosasaurs, a few iguanid lizards similar to the modern *Sauromalus*, a few anguinomorphs like the Recent "slow worms" and gila monster, some Platymota (monitors) and a few, newly evolved Serpentes. Some of these were burrowing forms, others resembled Recent boas.

Aves appeared in the Jurassic, but, perhaps because out-flown by pterosaurs, they remained uncommon throughout the rest of the Mesozoic. Only since the reptilian competition has been reduced have birds greatly flourished. This they have indeed done through the whole Cenozoic to date. They waxed rapidly in importance early in the Tertiary.

The first certain Mammalia are Cretaceous in age, although several Jurassic fossils are probably of this class, and some Triassic Ictidosauria, certainly at least intermediate, may already have produced milk for their young. It is clear that Cretaceous mammals were uncommon and small. The outstanding type was one that differed little from the modern opossum. With the advent of the Tertiary, mammals suddenly increased greatly in size and abundance, filling niches left vacant by the extensive reptilian extinctions.

It seems to me that one should find some explanation of the events in analysis of what perished and what survived.

Of the dinosaur extinction, A. S. Romer says it "is one of the most dramatic events in vertebrate history." Many hypotheses have been advanced to account for the observed facts. Not one of them has been proven; all are speculative, quite as much as the present one.

In 1937, while reading and discussing the above-described paleontologic events, an additional explanation occurred to me; that is to say, one more theory as to what may have caused the change in fauna at the close of the Cretaceous. Many to whom I have suggested this explanation point out objections, and quite properly. In all fairness it should be kept in mind, however, that grave objections are also offered against all the other opinions or hypotheses.

I suggest an event, or series of events, of brief heat, of temperatures high enough to kill exposed large animals in certain parts of the world.

My suggestion has been criticized because it presumably did not account for the

lack of change in flora at the end of the Cretaceous, and by another critic who argued that it did not account for the great change in flora at that time. As noted above, the evidence favors a Cretaceous vegetation much like that of the present. Romer suggests that lack of proper food plants caused the extinctions, but does not belabor the point. Modern type vegetation is today more nourishing than the gymnosperms and pteridophytes which dominated the Jurassic, and dinosaurs seem to have prospered more, rather than less, after modern vegetation appeared in the Cretaceous.

Brief heating would let enough vegetation escape to re-seed the world. Out-of-the-way areas of the sort represented now by New Zealand would probably survive. Many plants live as roots while destroyed above ground, and sprout again. Others survive catastrophes as seeds although their mature plants perish. The events that I postulate would selectively favor Arctic and sub-Arctic vegetation, and many Cretaceous plants that survived the Tertiary are such as now flourish in the cooler regions, or on islands.

A common suggestion or opinion is that egg-eating enemies brought about extinction of the large reptiles. Why should egg-eaters select those and spare the eggs of birds, lizards and turtles? Were dinosaur eggs larger than ostrich eggs, or Apteryx eggs? Flightless birds characterized the Cretaceous as much or more than now, and many egg-eaters can climb or fly. This theory may be correct, but is completely speculative.

Some experts suggest that the large reptiles perished because of pituitary abnormalities. They certainly had large pituitary glands, but they were so supplied for literally millions of years, probably more than a hundred million years. A million years ago man's ancestors were still apelike. The large reptiles had been obviously healthy and prosperous for this vast length of time, with over-sized pituitaries all that while. Why then should they all perish so nearly simultaneously, from such a well tolerated gland?

One opinion has it that the whole world became lethally cold, or a cold age that lasted comparatively long in geologic terms. This would certainly have killed the dinosaurs. This theory has the great merit of accounting for the preferential survival of birds and mammals. They have such effective insulatory body covering (feathers and fur) that they can be, and are, homoiosthermous. They endure cold now, and surely endured it in the Cretaceous, too.

World-wide cold would be more nearly complete in action than whatever-it-was that really happened. Palm trees survived, for example, and snakes and some lizards. Most significant, the geologist does not find any stratigraphic evidence of such a great ice age. The coldest epochs of the Pleistocene never froze the whole world; this theory is surely open to question.

Another hypothesis calls for a time of world-wide high temperature, again lasting comparatively long geologically speaking. This doubtless implies a gradual rather than instantaneous origin, and fairly slow recovery. It is quite certain that warmer than usual climates affect the continents from time to time. Tropical climate has prevailed in what is now north temperate region, probably several different times. One may suppose a hotter and hotter planet, even with equatorial regions too warm for animal life. But in this case, the dinosaurs would merely have migrated poleward. If our planet became hot enough to kill dinosaurs north of latitude 70, not much of anything would have survived anywhere. Sustained heat would have finally produced revolutionary changes even in the ocean. There is no stratigraphic record of such omnipresent lethal heat.

There is, however, logical reason to believe that heat was the doom of the dinosaurs; not long continued, but brief. Air temperatures may have been near boiling in the tropics, and up to 50°C. as far from the equator as latitude 50, but not with regular boundaries. Rather the fierce gales of heated air swirled here and there, missing some scattered small areas. Furthermore, where there was much snow to be melted, this melting cooled them to sub-lethal temperatures. Life went on in the sub-Arctic.

It would require many centuries to warm up the ocean; even the very surface heats slowly, and the warmer water will stay on top, only sinking after a long, poleward

journey. In fact, it cools notably before sinking. Hence the world's water changed little.

Let us see how the hypothesis of brief heat accords with the record of survivals and extinctions, why it might be preferred to other opinions.

As for vegetation—most mature vegetation would probably burn, but many roots survive, many seeds survive, and much snow-bound northern (and extreme southern) vegetation would survive even as mature plants. The trees and shrubs on mid-oceanic islands would be spared. When such an island is now denuded, for example, by a volcano, the rapidity with which it is reclothed in vegetation reveals that a nearly denuded world would be again green with plant life in a few thousand years.

Such brief heat would spare the completely aquatic animals, exactly as indicated in the fossil record.

Chelonia are not merely aquatic. They have an ability to "hold their breath" for hours at a time, under water. They may spend the winter in a torpid condition, so immersed in ice that a hot hurricane would do little more than thaw them awake. Chelonia did survive.

The air-breathing plesiosaurs perished, although this may have been in the mid-Cretaceous.

The Rhynchocephalia survived, and demonstrate how a small animal, not large like a plesiosaur, may hold its own in an isolated, out-of-the-way area, which New Zealand is. Furthermore, *Sphenodon* spends much time in crevices or burrows.

Crocodiles survived, perhaps on the same basis as the turtles. Conceivably, it might have been only one batch of eggs, well buried in mud, that lived through a catastrophe.

The pterosaurs could not hide; they all perished.

All the dinosaurs perished.

Many of the Squamata lived through, as follows: Lizards of the *Sauromalus* type survived. These today are noteworthy for their tendency to crawl back into cracks and fissures. Several aguinomorph lizards survived; they also are fossorial or crytophilous. Some monitors survived; today they are found chiefly on oceanic islands—perhaps they had a similar placement in the Cretaceous. The Serpentes survived preferentially, but as already mentioned, some were burrowing forms. The others were of the boa type, which, even today, hides amazingly. I have searched for them in the tropics. They were found, but always in my experience, hiding in a hollow tree. They lie in wait for the victim, now generally a mammal. This victim, perhaps an opossum, crawls into the cavity vainly seeking asylum from its other enemies, only to become a dinner for the snake. This doubtless happened to Cretaceous opossums, too. These lizards and snakes have such ecological placement and habits that they are exactly the ones that might be expected to live through a fiery tempest.

The birds and mammals survived best of all. The Cenozoic is their period; these two classes have dominated the land since the earliest Tertiary time. They can live in the snow-covered high latitudes. Undoubtedly they lived there in Cretaceous times as well as now. Even boiling hot air, blowing over miles of snow, would cool down to a breathable degree.

I believe that objective, unprejudiced contemplation will find considerable plausibility in the present hypothesis.

A wholly reasonable and proper question of course arises; what could have caused brief heat, such as has been postulated?

An historical event occurred, and reading its description caused me to consider the present hypothesis.

At eight o'clock in the morning of June 30, 1908, a shower of meteorities struck near Vanovara, Siberia; these are the so-called Tunguska or Podkamennaya meteorites. Effects were noticed that same day in the records of the barograph at Kew Observatory in England, some 5,000 kilometers away, and the following evening a peculiar sky-glow was noted in England.

Study of the site was later conducted (1928) by a party of Russian scientists, led by L. Kulik. His reports, and others, are summarized in a chapter of H. H. Nininger's book about meteorites, entitled "Our Stone-Pelted Planet." The fiery mass was seen coming from the northeast, and the terrific explosion was heard by the inhabitants of the cities of Yenisseisk, Krasnojarsk, Kansk, Nijneudinsk and Kirensk. An earthquake was felt as far away as Irkutsk.

At the point of impact there are numerous

craters 50 to 200 meters in diameter, but now nearly filled with water, vegetation and debris. The region is extremely wet and swampy.

In a circle of 20 kilometers diameter, the trees still stood, although scorched and carbonized by intense heat. Here the shock-wave struck nearly vertically.

Around this, to a diameter of about 60 kilometers, the trees were prostrate as well as carbonized, tops directly away from the center of impact, flattened by the terrific wind. An area of nearly a thousand square kilometers had been heated so that all animal life perished. This included several families of human settlers, at least 1,500 reindeer, and numberless smaller animals. This is one of the most sparsely inhabited regions on earth, or the human deaths would have been far greater and worldwide attention demanded.

A representative eyewitness report is that of a farmer named Semenov, who lived 80 kilometers from the point of impact. He saw the blinding blaze of light and almost at the same instant felt a heat so great that he thought his clothes would catch fire. Then there was darkness, or at least he could not see. About four minutes later the deafening explosion and air wave hurled him unconscious through the air, and partially demolished his house.

Yet this fall was of meteors that caused only a small fraction of the damage (crater size) of those that caused the crater at Winslow, Arizona, some 5,000 years ago, or the even larger Chubb crater in northeastern Canada. Other geologically recent meteoritic craters do not show, because of falls in the ocean (four-fifths of the earth's surface) or where vigorous erosion has obliterated them, as in the tropics.

One may profitably consider the Tunguska meteorite. It is only necessary to postulate a larger event of exactly the same kind, to implement the present hypothesis.

H. C. Urey has written authoritatively and interestingly on the history of the moon. He and others have shown that in the early time of our solar system the earth and moon were the targets of colossal bombardments. Some scientists assume that this bombardment ceased in the remote Pre-Cambrian, except for trivially small meteorites.

In late October 1937 the asteroid "Hermes" passed so close to the earth that even some astronomers envisaged the possibility of collision. It missed our planet by only some 480,000 miles, which is about the diameter of the moon's orbit, and only a little more than half the sun's diameter. Should we assume that never before in all the earth's history did any other asteroid come closer?

In view of the near approach of "Hermes," and the evidence of Chubb crater and Winslow, it would not be at all astonishing to discover that there have been three or four collisions of planetesimal size on our planet since the Cambrian—perhaps one every two or three hundred million years.

Heat of impact is amazingly effective. It has been discovered, for example, that battleship projectiles melt their way through several inches of steel armour as a result of the terrific heat energy of their slowing down. The energy of travel is converted to heat energy by the cessation of travel.

Meteorites that are slowed down by passage through the atmosphere become incandescent, and their outer surfaces not only melt, but even boil. Even stone and nickle-iron vaporize—the latter at about 2,500° C. Study of the surfaces of available meteorites amply confirms this.

The larger the meteorite (the greater its momentum) the less it is slowed down by passage through air. Small ones settle like drifting dust. Medium sized ones hit like cannon balls. One that was hundreds of meters in diameter might retain nearly its full interplanetary speed.

Kulik estimated the speed of impact of the Vanovara meteorite as well over 50 kilometers per second. Similar speeds for newly arriving meteorites are recorded by Nininger, LaPaz, Stocking and others. Much slower speeds are measured for the ordinary meteorite that has been slowed down to incandescence and is available for easy measurement.

There is sound reason to expect that no extra large meteorite will ever be found anywhere, under any conditions. By "large" I imply units over a hundred meters in diameter. None are found, for example, at Vanovara, or at Chubb Crater, and none so large at Winslow. One's first assumption

is likely to be that they are merely deeply buried, but another explanation is available.

Let us assume impact at the speed of only 10 kilometers per second, and cessation of motion within a depth or penetration of one kilometer. Iron at high temperatures has a specific heat of about 0.15, therefore the temperature generated by stopping would be

$$\frac{10^{12}\ \text{cm}^2/\text{sec}^2}{2\times 0.15\times\frac{\text{cal}}{\text{gm.}^\circ\text{C.}}}\times\frac{4.18\times 10^7\ \text{ergs}}{\text{cal}}$$

or a temperature of 6,666°, which is more than twice the boiling point of iron. Assuming that half goes outward and half goes inward, the entire projectile would still vaporize.

Let us assume a meteorite of 100 meters diameter. Its kinetic energy would be $MV^2/2$, its mass 3×10^7 tons or 3×10^{13} grams. The total calories possible from the conversion of this kinetic energy into heat energy would be 1.5×10^{25}, or enough to boil 10^{16} tons of water. In the entire ocean, there are only some 10^{18} tons of water. The energy sufficient to boil 10^{16} tons of water would be enough to boil 3×10^7 tons of iron, much of the surrounding earth, and still allow for terrific radiation outward into space.

An impact at 50 kilometers per second (five times as fast) would yield 212,890,625 times as much heat, an almost incomprehensible figure.

An impact at only 1 kilometer per second would still yield 1.5×10^{23} calories, enough to boil 10^{14} tons of water. Assuming that to boil iron requires ten times the calories required to boil the same mass of water, this heat would still vaporize 10^{13} tons of iron, whereas the meteorite mass was 3×10^7.

A meteorite so large as 100 meters diameter would instantly heat the vicinity of its impact; a region about twice its diameter, to vaporization, a much larger area to incandescence, more than a thousand kilometers diameter to the boiling point of water, and the whole world notably but briefly.

The size of the crater does not reveal the size of the individual unit. For example, Winslow Crater may have been made by a cluster or shower of separate meteorites, each small enough to be considerably slowed by the atmosphere. On the other hand, one or more of the units may have been so large as to vaporize, even there.

When iron vaporizes and cools, it precipitates in the form of minute spheres. Exactly such spheres are found around the Winslow Crater.

The Vanovara meteorite was certainly lethal to a diameter of 60 kilometers. The much larger Winslow meteroite was probably lethal for a diameter of 600 kilometers. One much smaller than the asteroid "Hermes" would be deadly for thousands of kilometers—a lethal belt actually circling the equator more than once. If it happened today, the human survivors might be only a few Eskimos, but they would re-people the earth in a few centuries. As on Krakatoa, they would find vegetation springing up from seeds and roots; there would be interesting survivors from Kerguelen and some mines in Siberia.

In my short lifetime we have witnessed the astronomically close approach of the planetesimal "Hermes." There is every reason to believe that in the remote past others had orbits that brought them even closer to ours. A few such may have existed and then ceased by final involvement with the earth's gravitational field, a spiral approach, and collision.

In a similarly short time the world has been struck by a meteoritic cluster that devastated a large area in Siberia. If this area had been in the United States, American scientists would have been impressed. They would not regard danger from impact as being preposterous, an assumption which is now common.

It is not fantastic to consider the likelihood that an extra large impact affected this planet some sixty million years ago. No human being was here to see it, or study it with radar. But just such extinctions occurred, and just such survivals occurred, at the end of the Cretaceous, as would be expected to occur as the result of impact from a planetesimal or an extra large shower of meteorites.

May we not take this into consideration as possibly having been the doom of the dinosaurs?

MANUSCRIPT RECEIVED JULY 18, 1955

A BLANCAN MAMMALIAN FAUNA FROM WICHMAN, NEVADA

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ABSTRACT—A small mammalian fauna from Mineral County, Nevada, is dated as Blancan in age on the basis of *Paracamelus*, *Plesippus*, and an advanced gomphotheriid. This is the first reported Blancan fauna from Nevada and the central part of the Great Basin.

INTRODUCTION

Most of the material described below was collected by R. A. Stirton of the University of California Museum of Paleontology who has most kindly made it available to me for description. The locality was discovered by Stirton in 1939 and was briefly described the same year (Stirton, 1939). The site was visited again in 1947 by Stirton and a party from the Museum of Paleontology and, in the following year, by the author and Messrs. Willis Pellitier and Henry Herlyn.

Collecting throughout Nevada by parties from the Museum of Paleontology was made possible through the generosity of the late Miss Annie M. Alexander. The figures were prepared by Mr. Owen J. Poe of the Museum of Paleontology.

LOCALITY AND OCCURRENCE

The Wichman fauna was obtained from a small outcrop in the Missouri Flat area 4 miles north of the Wichman Post Office (discontinued) and about 1 mile west of the Yerington-Fletcher Station Road (Nevada State Highway 3C) opposite the headquarters of the East Walker Ranches in Mineral County, Nevada.

Designated as University of California Locality V3914, the fossils were found in pockets of unconsolidated quartzitic sand with small lenses of fine pebbles. The pockets are formed in rhyolite tuff which forms part of the sediment along the west side of the valley of the East Walker River. The exposed pre-Quaternary sediments are listed in the following section:

	Feet
Gray gravel with clay	18
Rhyolite tuff	8
Gray gravel with tuff	4.5
Rhyolite tuff	9
White clay	5
Rhyolite tuff containing pockets of unconsolidated quartzitic sand and small lenses of pebbles	20

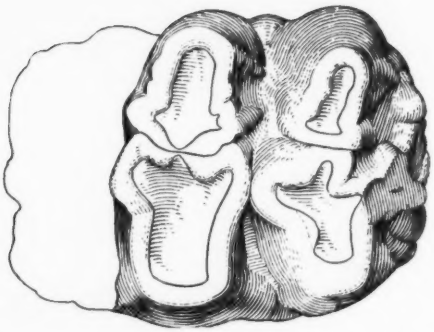
The mammalian remains from these pockets consist of isolated waterworn bones and teeth. They occur in the pockets, and as float on the surface of the lower tuffaceous member. No remains have been found in the tuffs except in the walls of the pockets.

The origin of these pockets leads to some interesting speculations. They range up to 3 feet in diameter and are at least 4 feet deep. There is an indication that some of them extend laterally toward the valley as small tunnels 6 to 8 inches in diameter. This fact immediately suggests that they may have originated as the familiar "tunnels and funnels" which are found in so many Tertiary deposits in the western United States.

Similar pockets are often found in tuffaceous, clayish, or bentonitic beds in arid regions. They seem to be formed by a combination of surface and subsurface weathering under conditions of drought and short periods of heavy rainfall. Surface water may collect in small depressions and slowly sink along fractures until released into nearby gullies. In this way rather large funnels with drainage tunnels may be formed. The mantle may develop into several inches of expanded and loose weathered material which is covered with a thin sun-baked cap. Active erosion then occurs only under conditions of heavy runoff.

It is conceivable that pockets of this sort were formed in the Wichman tuffs at a time when the nearby East Walker River was running at a higher elevation that it now is. A higher position of the river during post-Clarendonian time is indicated by its superimposed position on the basement complex in the Coal Valley area a few miles

[1] This material was prepared while the author was with the Museum of Paleontology, University of California.



TEXT-FIG. 1.—Gomphotheriidae, gen. indet. ?M_1, UCMP 38354, occlusal view. ×3/5.

to the south. The accumulation of sand and bone in these pockets may represent the deposition from a single flood that spread out over the valley floor and inundated the area; or the deposit may be the result of sheet wash sweeping down from the higher ground to the west during a period of extreme rainfall. The uniform character of the pocket fill and the water-worn condition of the bones is suggestive of the first explanation.

A possible objection to this hypothesis is the occurrence of some bone fragments in the tuff of the walls of the pockets. An explanation of this may lie in the fact that the funnels which have been observed in other areas have a two to three inch lining of soft partially weathered and puffed up material. When the Wichman pockets were filled with sand, fine pebbles, and bones, some of the bones may have become lodged in the weathered and soft sides of the funnels. Later compaction of the weathered surface would weld the bone fragments in place.

SYSTEMATIC PALEONTOLOGY

Order PROBOSCIDEA

GOMPHOTHERIIDAE, gen. indet.

Text-fig. 1, 2

Ten cheek teeth, many foot elements, and a short section of tusk are referable to this family. Two of the cheek teeth are complete and unworn. One of these, a left upper molar (UCMP 35355), has 4½ crests, the double trefoils are strongly developed in the first valley and become progressively reduced in the posterior valleys, the third valley is open to the bottom, there are small conules on the posterior sides of the labial half of the crest. The other unworn tooth (UCMP 35354) is a right lower tooth and possibly a first molar. It has three full crests and a greatly reduced posterior lophid. The double labial trefoils are equally developed on each crest, but there are no conules in the valleys. The tusk fragment (UCMP 39661) is nearly round in cross section, measuring 86.3 by 85.3 mm. at the larger end. There is no sign of enamel on the surface.

In size and form the trefoils of the cheek teeth are similar to those of *Gomphotherium simpsoni* (Stirton), but there are additional small conules on the upper molar and the lateral edges of the lophs are not as bulbous as those of the above species.

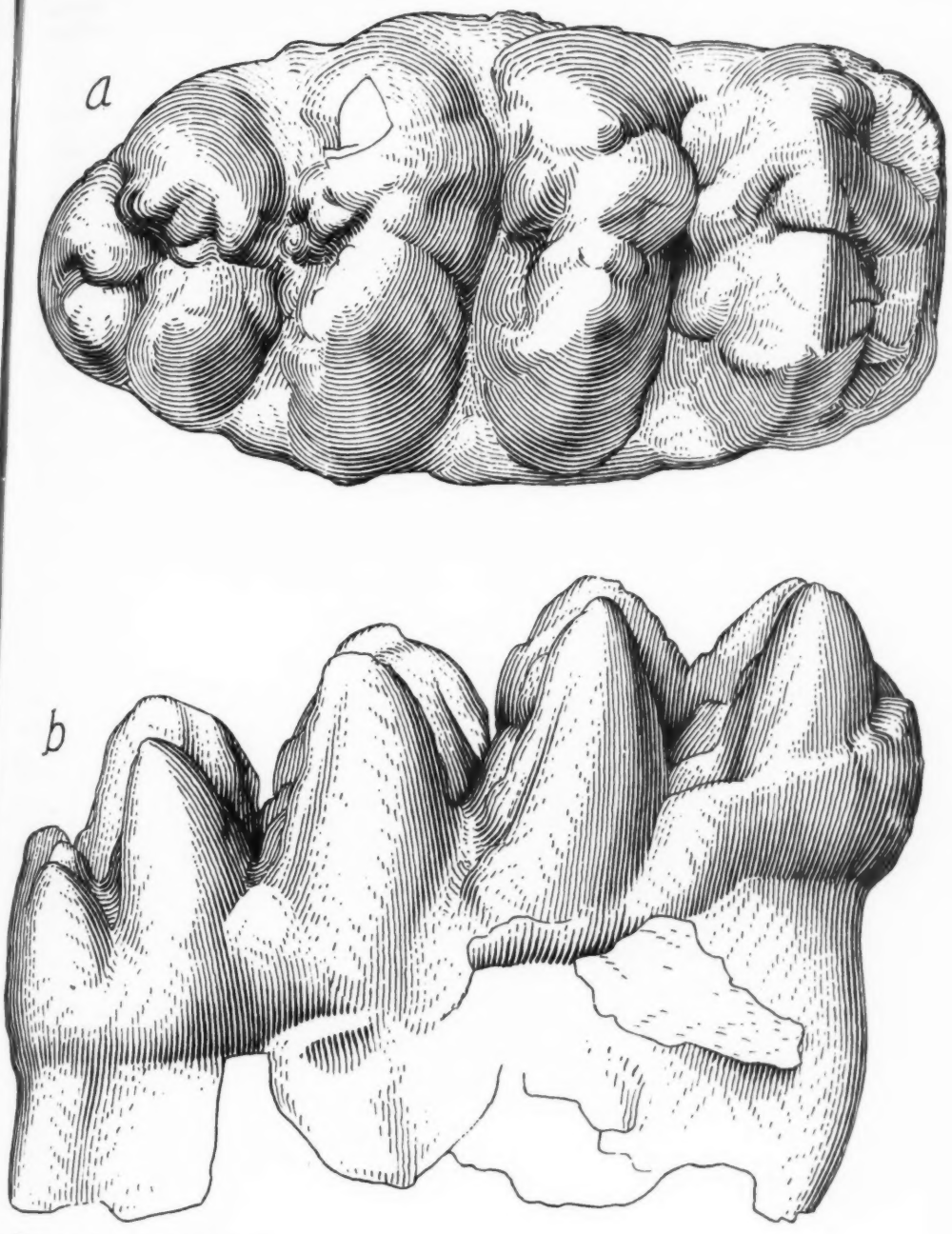
Order PERISSODACTYLA

EQUUS (PLESIPPUS) sp.

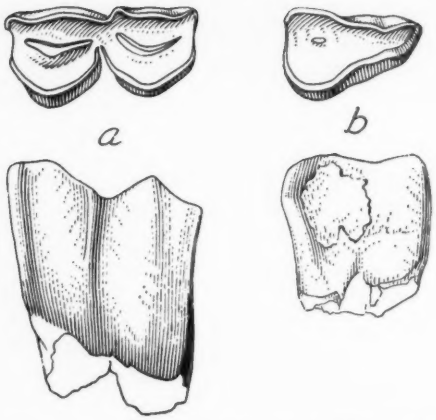
Twelve upper and 24 lower cheek teeth showing all stages of wear, and a small collection of limb elements were found in the sand pockets. All but two of the lower cheek teeth have a hippotigrene-shaped valley between the metaconid and the metastylid. The upper cheek teeth in this series closely resemble those of *E.* (*P.*) *shoshonensis* (Gidley) in over-all dimensions, height of crown, curvature, and pattern of the fossette borders. The size and shape of the protocones vary considerably; some are very long and narrow, while others are short, massive and round. In general, the protocones are shorter and more rounded than in *E. shoshonensis*. Several teeth show very heavy mesostyles which are not so apparent in the available specimens of *E. shoshonensis* from the Hagerman lake beds.

The protocones resemble those of *E.* (*P.*) *simplicidens* Cope, but the fossettes of the Blanco species are not as open as those from Wichman which are generally more crescentic in shape. The enamel pattern of the lower cheek teeth more closely resembles the type found in *E. simplicidens* as the premolars do not display the complex crenulations commonly found in the Hagerman species.

A comparison of isolated teeth with a series from any species of the larger Blancan horses shows similarities and differences



TEXT-FIG. 2.—Gomphotheriidae, gen. indet. Left upper molar, UCMP 35355: *a*, occlusal view; *b*, labial view. ×¾.



TEXT-FIG. 3.—*Paracamelus* sp. *a*, M_2, UCMP 35357; *b*, P_4, UCMP 39659. Occlusal and lingual views. ×3/5.

which would permit a number of specific identifications as the species of these horses are now diagnosed. Therefore, it is felt that a specific designation for these teeth is unwarranted.

The associated limb material includes a metacarpal, which from its short stocky nature approaches that of the caballine species *E. scottii* Gidley from the Pleistocene. This in itself does not indicate a relationship, but perhaps indicates that the Wichman horse is specialized in this character in a different way than *E. shoshonensis* and *E. simplicidens.*

Order ARTIODACTYLA
Family CAMELIDAE
PARACAMELUS sp.
Text-fig. 3

A moderately worn P_4 (UCMP 39659) and a M_2 (UCMP 35357) may be referred to the genus *Paracamelus.* The P_4 is longer antero-posteriorly and higher crowned than that of *P. gigas* Schlosser from China and the forms from the Hemphill and Smiths Valley faunas. The outline of the occlusal surface is quite similar to that in the North American forms. The M_2 is nearly identical in shape and crown height to the specimens from the Hemphill fauna.

Table of measurements (mm.)

	Wichman (39659)	*P. gigas* (after Zdansky)	Hemphill (30869)
P_4, A-P diam.	32.6	26.0	25.6
P_4, Tr. diam.	18.0	16.5	15.0
	(35357)		
M_2, A-P diam.	43.7	44.0	37.8
M_2, Tr. diam.	21.0	29.5	23.3

It is unfortunate that this record is so meager, as it represents the latest reported occurrence of this genus in North America.

?CAMELOPS sp.
Text-fig. 4

A fragment of the anterior half of a left P_4 (UCMP 39660) is questionably referred to this genus. Its occurrence in this fauna represents the earliest recorded appearance of this genus which is usually considered to be Pleistocene in age.

TEXT-FIG. 4.—*?Camelops.* Fragment of anterior half of left P_4, UCMP 39660. ×1.

CERVIDAE, gen. indet.

A portion of the hind leg including the astragalus, calcaneum, fibula, and a portion of the proximal end of the metatarsal (UCMP 35392) are cervoid in character. The calcaneum and the astragalus are similar in size and shape to those found in the large Recent species of *Odocoileus* and the small species of *Cervus.* The metatarsal does not have the well developed ridge on the anterior face that is so characteristic of the modern species of these genera.

CONCLUSIONS

Although the fauna of the Wichman sand pockets is very small and does not contain very much in the way of diagnostic material, it is of interest as it is the only fauna of Blancan age known from Nevada and the central portion of the Great Basin.

The Blancan age for the fauna may be established on the basis of the advanced gomphotheriid and the presence of *Paracamelus* and *Plesippus.*

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CALCITE AND ARAGONITE IN FORAMINIFERA[1]

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ABSTRACT—X-ray diffraction analysis of Recent calcareous specimens of Foraminifera indicates that the mineralogic nature of tests is a generic characteristic, with the few genera that have aragonite tests being related at the family level. Environment appears to have no influence on the presence of calcite or aragonite and the two minerals do not occur together in the Foraminifera.

CALCAREOUS tests of Foraminifera occur both as calcite and as aragonite (Bandy, 1954; Troelsen, 1955; Switzer & Boucot, 1955). Studies have been made through the use of Meigen's reaction (Troelsen, 1955), and investigations by the present authors are under way using X-ray diffraction analysis to determine whether the separation between calcite and aragonite tests falls along family lines, generic lines, ecologic lines, geographic lines, or other yet unrecognized lines of separation. A definite separation along family lines has been established (Troelsen, 1955). Individuals of a certain few genera, all of which belong in the families Ceratobuliminidae (Troelsen, 1954, p. 450, 451) and Robertinidae (Hofker, 1951, p. 379), are composed of aragonite regardless of their habitat or their geologic age.

The purpose of this investigation is twofold: (a) to throw additional light on the classification value of the mineralogic nature of calcareous tests in Foraminifera, and (b) to determine whether the mineralogic nature follows any patterns dictated by environment.

The present writers have selected about 120 genera of calcareous Foraminifera for examination by X-ray diffraction to establish the mineralogic nature of their tests. Recognizing that the total number of genera in the order Foraminifera is a highly subjective matter, we have elected to base our selection largely but not exclusively on the Cushman classification (Cushman, 1948) wherein are included 751 genera. About 47 percent of these genera are removed from consideration because no Recent species of them are known, and about 21 percent more are removed from consideration because their tests are agglutinated. From the remaining 239 genera, about one-third of the Foraminifera genera known, we have selected half, about 120, making our selection from the most abundant and widely distributed genera in order that our results shall be applicable to the greatest number of specimens, species, and genera. Even granting the possibility that the total number of 751 genera listed by Cushman (1948) may eventually be doubled, we estimate that the 120 genera being studied will include between 75 and 90 percent of the specimens known from Recent faunas. Even though specimens as old as Early Cretaceous have been found in several instances with apparently unchanged aragonite tests (Troelsen, 1955, p. 50), the possibility of inversion of aragonite to calcite would invalidate any results obtained by examination of fossil specimens. Hence our study is being confined to Recent specimens. Final results will be tabulated with specific determinations of the specimens studied and complete locality data.

Individual specimens of various genera have been analyzed qualitatively for calcite and aragonite by X-ray diffraction. Owing to the small size and paucity in numbers of the foraminiferal tests, the Debye-Scherrer camera diffraction method was used rather than the goniometer diffractometer with strip-chart recorder. A nickel-filtered copper target was employed in conjunction with a 114.6 mm. diameter camera. A 57.3 mm. camera was tried in an attempt to reduce the exposure time; however, resolution was considered inadequate for very small percentages of aragonite.

Each specimen was first mounted intact on the end of an ethyl cellulose spindle, using gum arabic as an adhesive, and con-

[1] Publication authorized by the Director, U. S. Geological Survey.

tinuously rotated through 360° in the X-ray beam. Exposure time varied from 15 to 24 hours depending on the size of the specimen; the smaller tests required a longer exposure time to resolve the lines for very small percentages of aragonite.

Several times the original X-ray analysis of an unbroken specimen indicated the presence of minor amounts of aragonite with calcite. Each of these specimens was re-examined as follows: The shell was carefully cut open with a razor blade, and any detrital material inside the shell was removed with water and a fine brush. Then a diffraction pattern was taken of a fragment of the cleaned test. With each specimen an attempt was made to include a portion of the outside wall as well as the internal structure of the test. In every specimen where the authors found both calcite and aragonite in the original diffraction pattern, only one of these two minerals was found in the pattern of the "cleaned" shell fragment. This indicates that the test is composed of either aragonite or calcite, not a mixture of the two. Apparently the detrital material invaded the test through its pore spaces after the organism had died.

Of the specimens that were composed of calcite, approximately one-third showed a displacement of the principal calcite diffraction line from its normal position at 3.03 angstroms. The line position ranged from as low as 2.98 angstroms to its normal 3.03 angstroms. Although the large specimens increased the width of the diffraction lines, the size and orientation of the mounted specimen appeared to have no effect on the position of the line. The variance from 3.03 angstroms was possibly due to the presence of magnesium in solid solution with the calcium as indicated by Chave's work (1952, 1954). There were no changes in the positions of the diffraction lines for tests composed of aragonite.

Lowenstam (1954a, 1954b) has shown that in representatives of at least three phyla—Bryozoa, certain genera of mollusks, and the polychaete family Serpulidae—calcite and aragonite coexist. He has shown that there is no predetermination for a wholly calcite or wholly aragonite shell, but that ecology influences the aragonite-calcite ratio because aragonite increases with an increase in temperature. Preliminary results of the present study indicate that this concept does not apply to Foraminifera.

Switzer & Boucot (1955, p. 529–531), in their list of results of 50 determinations made, include determinations of 15 Recent calcareous genera. In order not to duplicate X-ray diffraction determinations already made, we have combined our results (68 determinations made so far) with those of Switzer & Boucot (1955). Thus a total of 83 Recent calcareous genera has so far been examined by X-ray diffraction. Of these 83 genera, only 5 are found to be wholly aragonite, while 78 are calcite. None showed indications of combined aragonite in the shell. These 78 calcite genera represent both floating and bottom-dwelling forms from various localities in the Pacific, Atlantic, and Mediterranean. The environments of these genera vary in latitude; in depth, temperature, and salinity of the water; and in aragonite and calcite content of the bottom sediments.

As preliminary clues to the effect of environment on the mineralogical nature of calcareous tests of Foraminifera, we examined, in one case, specimens of an aragonite species and, in another case, specimens of several species of a calcite genus with the following results. The specimens of an aragonite foraminifer, *Höglundina elegans* (d'Orbigny), came from three widely separated geographic locations (Gulf of Mexico, Mediterranean Sea, Pacific Ocean). All the specimens lived under approximately the same ecologic conditions, because this species seems to be rather limited in its ecologic tolerance. The three samples of *H. elegans* show no variance from a wholly aragonite test. The specimens of three different species of a calcite genus, *Cassidulina*, were from different ecologic environments (shallow tropical lagoon, deep water on a Pacific seamount, and deep, cold water off the Falklands). The three species of *Cassidulina* show no variance from a wholly calcite test.

Four of the five aragonite genera thus far determined by X-ray diffraction were represented by Recent specimens. In addition,

four other aragonite genera, determined by Meigen's reaction (Troelsen, 1955, p. 50), were represented by Recent specimens. No ecologic factor seems to be common to these eight Recent genera, as they range in depth from 27 to 494 fathoms, and in latitude from the tropics to the Arctic.

The results obtained thus far suggest that:

(a) The mineralogic nature of Foraminifera tests is a generic characteristic.
(b) Most Foraminifera have calcite tests.
(c) The few Foraminifera having aragonite tests are related at the family level.
(d) No combinations of aragonite with calcite occur in the Foraminifera.
(e) Ecology appears to have no influence on the mineralogic content of Foraminifera as regards aragonite and calcite.

The tentative results obtained suggest the need for further study, including determination of magnesium content as a possible function of ecology.

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MANUSCRIPT RECEIVED AUGUST 15, 1955

NOMENCLATURAL NOTE

DESIGNATION OF TYPE OF *PLECTORTHIS PLICATELLA MINNESOTENSIS* WEISS, 1955

MALCOLM P. WEISS
The Ohio State University

Circumstances prevented the comparison of the proof of a recent article (Weiss, 1955) with the manuscript. Two items omitted from that paper are presented here. First, of the specimens of *Plectorthis plicatella minnesotensis* Weiss (1955, p. 768), number T6704 is designated the holotype (Pl. 69, fig. 6), and T6706 is designated the paratype (Pl. 69, fig. 5). Secondly, figure 12 of Plate 70 is described as follows: *Rhynchotrema* cf. *R. plena* (Hall); dorsal interior showing septalium without cardinal process, ×1, T6702, Sardeson Collection, middle part of Decorah formation (Bed 5 of Sardeson), Cannon Falls, Minnesota.

REFERENCE CITED

WEISS, M. P., 1955, Some Ordovician brachiopods from Minnesota and their stratigraphic relations, Jour. Paleon., vol. 29, p. 759–774.

JOURNAL OF PALEONTOLOGY, VOL, 30, NO. 1, P. 220–221, JANUARY 1956

NOTICES

AN ADDITION TO THE AVAILABLE U. S. GEOLOGICAL SURVEY TECHNICAL FILES IN PALEONTOLOGY[1]

by

Members of the Paleontology and Stratigraphy Branch
U. S. Geological Survey, Washington 25, D. C.

An objective technical file concerning the Cambrian fossils of the World has been prepared by personnel of the Paleontology and Stratigraphy Branch of the U. S. Geological Survey from an earlier file compiled by Dr. C. E. Resser of the U. S. National Museum. This is now available as an Open File Report of the U. S. Geological Survey and positive microfilm or paper facsimile copies may be purchased at cost of reproduction by filing a prepaid order with the Map Information Office, U. S. Geological Survey, Washington 25, D. C. Charges are based on current materials and labor costs and will be subject to change without notice. For this reason, prices listed below cannot be guaranteed.

[1] Publication authorized by the Director, U. S. Geological Survey.

As in previous releases of technical files of the Paleontology and Stratigraphy Branch, no guarantee to the accuracy of the file is made. It consists primarily of uncritical compilations in large part brought together by clerical help, and commonly not checked as to accuracy or consistency of usage. On the other hand, this file is a useful research tool in judicious hands, and it is being made available to the profession at large. The nature of the material and the large investment of professional time that would still be required to put it into shape for publication has determined the form of release.

The technical files of the Paleontology and Stratigraphy Branch that are now available, the number of microfilm rolls and images, and prices are as follows:

Item	Duplicate 16 mm. microfilm	Paper facsimile	
		Continuous roll 5 in wide	Cut to consistent size
Objective synonymy catalog of the Cambrian fossils of the world (as recorded through 1954) (5 microfilm rolls; more than 14,000 images)	$ 8	$ 161	$ 224
Compendium of paleobotanical species (as recorded through 1951) (28 microfilm rolls; 135,490 images)	56	1,017	1,313
Paleobotanical bibliographical index (as recorded through 1951) (5 microfilm rolls; 17,356 images)	10	181	237
Mesozoic species index—North and Central America, including the Caribbean (as recorded through 1951) (8 microfilm rolls; 25,459 images)	16	290	378
Mesozoic species index—South America (as recorded through 1951) (3 microfilm rolls; 8,345 images)	6	109	141
Cushman catalog of Foraminifera (as recorded through 1951) (33 microfilm rolls; 118,967 images)	66	1,198	1,550

The original records and subsequent additions to them remain available in the Survey's offices in the U. S. National Museum, and with the Museum's "Cushman Collection."

Other technical records of the Survey's Paleontology and Stratigraphy Branch on file in its offices at the U. S. National Museum and available for inspection on the premises, but not available for duplication and sale, are as follows:

	Cards
Cenozoic card catalog and bibliographies (incomplete and in revision)	143,000
Carboniferous and Permian synonymy catalog (a subjective index)	18,300
Pre-Mississippian bibliographies and faunal index (incomplete and in revision)	15,000
Diatom species index	40,000
Conodont synonymy index (a subjective index)	5,200

MANUSCRIPT RECEIVED AUGUST 21, 1955

NOTICE ON ZOOLOGICAL NOMENCLATURE

Notice is hereby given that the possible use by the International Commission on Zoological Nomenclature of its Plenary Powers is involved in applications relating to the under-mentioned names:

Items included in Part 7 of Volume 11 of the Bulletin of Zoological Nomenclature, scheduled for publication on July 7, 1955:

1. MAYAITIDAE Spath (L.F.), 1928 (Class Cephalopoda, Order Ammonoidea), validation of (p. 229–231) [Z.N. (S.S.) 884].

Items included in Part 9 of Volume 11 of the Bulletin, Scheduled for publication in January 1956:

1. *Phillipsinella* Novák, 1886 (Class Trilobita), validation of [Z.N. (S.) 757].

2. SEGUENZICERATIDAE Spath (L.F.), 1924 (Class Cephalopoda, Order Ammonoidea, suppression of [Z.N. (S.) 931].

Any specialist who may desire to comment on the foregoing applications is invited to do so in writing to the Secretary to the International Commission (Address 28 Park Village East, Regent's Park, London, N.W. 1, England) as soon as possible. Every such comment should be clearly marked with the Commission's File Number as given in the present notice.

Extracted from notes from FRANCIS HEMMING, Secretary to the International Commission on Zoological Nomenclature, dated June 27 and December 15, 1955.

JOURNAL OF PALEONTOLOGY, VOL. 30, NO. 1, P. 222–236, JANUARY 1956

SOCIETY RECORDS AND ACTIVITIES

NOMINATIONS FOR OFFICERS IN THE PALEONTOLOGICAL SOCIETY FOR 1956–1957

In accordance with the provisions of Chapter III, Section 2 of the By-Laws, the Council of the Paleontological Society announces the following nominations for the offices in the Society for 1956–57:

For President: G. ARTHUR COOPER, Washington, D. C.
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In accordance with Chapter III, Section 2 of the By-Laws it is provided that "Any twenty members may forward to the Secretary other nominations for any or all offices. All such nominations reaching the Secretary at least sixty days before the Annual Meeting shall be printed, together with the names of the nominators, as special tickets."

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